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Oregon Agricultural College
Experiment Station

Department of Soils

Farm Drainage

By

W. L. POWERS and WARD CRETCHER

CORVALLIS, OREGON

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SUMMARY

(1) This bulletin describes different types of wet land in Oregon, the need and value of drainage for each type and experiments to determine the most suitable depth, distance apart, and sizes for field drains, as well as methods of installation and cost, and also gives information regarding the drainage situation in Oregon in general.

(2) There is in the State a great variety of wet lands of which three classes are easily chief; namely, white land, marsh land, and alkali land. Drainage of much of this wet area appears to be feasible, as good quantities of plant food and friable layers have been found therein.

(3) The aim in drainage should be to get the most drainage at the least cost, to secure the highest possible efficiency for every hundred feet of tile employed.

(4) Subsoils are more important than surface soils in determining drainage qualities of land. A study should be made of subsoil and groundwater conditions and the drains so located as to encounter excess water in the most porous layers.

(5) Studies of subsoil and ground water in white land generally show a friable streak of 33 to 36 inches depth and show also that tile placed in these areas have lowered the water table most promptly. The water table is lowered for 25 to 30 feet back from the tile within twenty-four hours after saturation.

(6) A depth of about 36 inches and distance between tile lines of 60 to 66 feet has been found most effective for lateral drains in typical white land, while deeper drains are desirable in the less retentive areas.

(7) Experiments indicate a suitable depth for tile to be 4 feet and distance of 80 feet for tide land; while in irrigated lands, as in Malheur Valley, drains 8 to 9 feet deep have controlled the water table, a distance of 660 feet laterally.

(8) Measurements of outflow in Willamette Valley indicate that main drains should have a capacity of ⅓ to ½ acre inch run-off to the acre in twenty-four hours for areas up to forty acres and one-third inch for larger fields as the total percentage run-off in the Willamette Valley is large. On the Coast ¾ inch to one inch is a suitable drainage coefficient.

(9) Since drainage is costly and white land subsurface is retentive, farm operations should aim to aid water in entering the tile. When drained fields are in clover, a larger outflow from tile and less surface water have been observed, and the structure and fertility of the land gradually improves.

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(10) Reports from farmers having over four hundred miles of tile in operation in the white land and other wet land in Oregon, show that tiling has generally been successful here.

(11) The tendency is toward larger tile in place of small open ditches. A combination of tile with a surface run frequently is good practice.

(12) Nature has determined the general location of ditches, and the size of the natural channel is an index to the required capacity. The grade should be low enough to receive the discharge from all laterals.

(13) Careful construction will return good interest by lessening maintenance fees.

(14) The farmer should study subsoil and ground water conditions in wet areas and then view out a full system of drains with the aid of a level, if necessary. The system may be installed in units, the most necessary parts first, but it is best to order tile in car lots. The farmer should make a study of drainage so that he can superintend and inspect his own work. He should sketch the tile lines installed and note results, extending the system as needed.

Farm Drainage

By

W. L. POWERS and WARD CRETCHER

INTRODUCTION

No other state offers a greater variety of drainage problems than does Oregon. There are about half a million acres of marsh land to be reclaimed on the coast, in the lake counties, and along the Lower Columbia and other streams. There are seeped lands in the hills of Western Oregon and in the irrigated valleys of Eastern Oregon, and there are alkaline lands both under irrigation and in the virgin state which it is feasible to reclaim at present. There are perhaps two million acres of wet land in the Willamette Valley and other valleys of Western Oregon that will be greatly improved by under drainage. In this valley in early spring, thousands of acres of land are too wet to work and in late summer the same lands are baked, and bear only one-half the crop that they could be made to yield by drainage. Altogether, there are in Oregon at least three million acres of wet land that can be reclaimed or greatly improved by drainage. This is an area larger than that reclaimable by irrigation in Oregon; an area equal to one-third of the total land in farms, or about one-half of the improved land in farms in the State, as given by the last census. Few people realize the great importance of drainage in the development of the farm lands of Oregon. Based on an increase in crop returns of $10 an acre, the increased production due to drainage would add $30,000,000 to the annual agricultural production, and over $100,000,000 to the permanent land value of the State. Drainage of our wet lands will become of increased importance with more intensive development of the agricultural resources and increase in the intrinsic value of the surrounding naturally drained upland.

The first tile drains laid in Oregon, placed about forty years ago in the vicinity of Scholls, are still working. The practice of drainage has spread until we now have records of over four hundred miles of tile drains in Oregon, about ninety-eight percent of which are in successful operation. The Oregon Experiment Station has been a consistent advocate of farm drainage and has conducted experiments, published articles, and given assistance to farmers and districts in laying out their drainage systems. The State Drainage Association was organized in 1915 and a modern District Drainage Law secured, so that in recent years the use of tile for farm drainage has rapidly increased. The Experiment Station, in cooperation with districts, has made during the past few years soil and topographic surveys of five hundred thousand acres included in proposed projects. Fifty drainage districts are being organized and a dozen others have been found feasible. Feasibility of drainage for any given area depends upon location, demand for land, time and cost of reclamation, soil fertility, and the practicability of engineering features.

Lands needing drainage in Oregon are generally well supplied with plant food and are mostly located where there is a remarkably long growing season. They are generally within reach of market and free from timber or rock. It is believed that much of this wet land will now pay a better rate of interest on the total investment if drained, and the time seems ripe for extensive drainage development. Our wet and arid areas offer the main opportunity for expansion of food-producing areas and of increasing our rural population. When any given area is reclaimed it adds to the wealth-producing area of the State for all time.

The aim in designing a drain system should be to get the most drainage at the least possible cost and to secure the highest possible efficiency for each hundred feet of tile employed. This bulletin is written to describe the progress of drainage in this State, to point out the best methods to follow as indicated by experimentation and experience, and to advise and encourage the increasing numbers seeking information along the line of land drainage. The demand for information on land drainage has been heavy and the supply of the previous bulletin on this subject has been exhausted.*

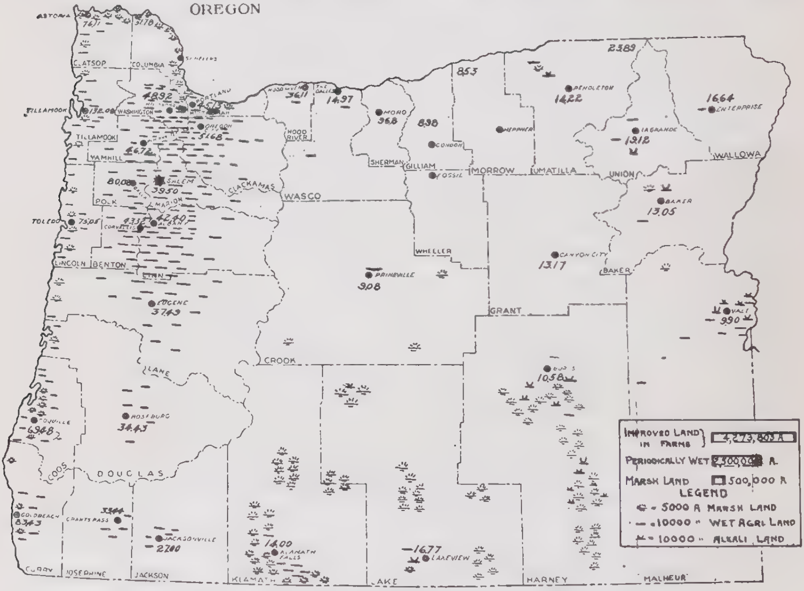

Fig. 1. Amount and distribution of wet land and of precipitation in Oregon.

I. SOILS AND SOIL WATER AS RELATED TO DRAINAGE

Wet Soils. Soil and water are the two substances we deal with primarily in drainage. Soil is composed of small particles irregular in size and shape, thrown together promiscuously. The pore spaces between the particles are continuous, forming innumerable finely divided channels which are occupied by either air or water. In a well-drained soil the small particles form in clusters, being held in place by cementing material present in the soil. This increases the pore space and therefore the usable moisture and air capacity. In wet, undrained soils, the cementing material that might have held the soil particles in clusters has been dissolved and the finer particles of soil are filtered into the interstices between the larger particles, making a minimum of pore space for usable moisture and air. Soil in this condition is more impervious. The arrangement of a soil in good tilth is similar in structure to popcorn balls, while the poor soil structure resembles concrete.

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*Powers, W. L., and Teeter, T. A. H. Drainage of White Land and Other Wet Lands in Western Oregon, Oregon Agri. Col. Exp. Sta. Bul. 137 (1916).

Subsoils are more important, from a drainage standpoint, than are surface soils. Subsoils are usually finer in texture; and hard-pan, shale ridges, or other impervious strata are apt to occur, which cause ponding and interfere with the movement of free water through the soil. Fine-grained, impervious soils are more difficult to drain, due to hard layers through which the water will not move as fast as it is received. Sandy or gravelly layers in the subsoil offer channels through which seepage water will move and in which drains may be placed to collect excess water. The chief wet soils of the State are: the white land of the Dayton Soil Series, the peat and muck soils of the marsh, tide, and overflowed areas, and the alkali areas of the irrigated sections.

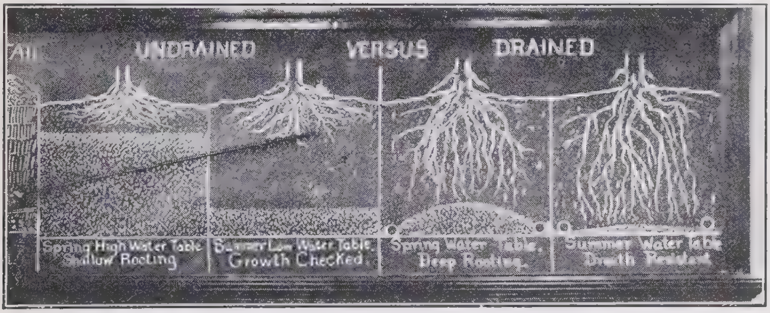

Fig. 2. Effect of drainage on roots and drought.

"White land" is the local name applied to the most important wet soil type in the State. It occurs chiefly in flat prairies of the Willamette Valley and is used for pasture or spring oats. Sorrel, tar weed, velvet grass, and dog fennel thrive on wet areas of this type. Physical analyses class this soil as silty clay loam. Physical analyses of white land made by C. V. Ruzek at the Oregon Experiment Station are given below.

TABLE I. PHYSICAL COMPOSITION OF WHITE LAND FROM DRAINAGE PLOTS

Soil sample	Fine gravel	Course sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
	%	%	%	%	%	%	%
Surface gray silty clay loam	1.52	1.70	0.54	1.46	10.44	63.73	19.86
Subsurface blue clay	0 00	0.48	6.54	6.52	9.92	44.39	33.64
Subsoil yellow silt loam	0.00	0.84	1.04	4.18	16.60	58.79	17.45

The surface soil is underlaid with an impervious subsurface layer of blue clay, which hinders percolation. Below this there is a yellow silt loam subsoil. This soil is easily puddled, and such practices as continuous grain farming, wet plowing, or pasturing in wet weather, have aggravated this condition and developed a "plow sole" or compact layer just below the furrow slice. The type is closely associated with the brown valley loam which occurs in elevated, naturally drained places on these prairies, the deep subsoil of both types being very similar. The color of this wet land is light gray before reclamation, but a darker color develops with drainage and constructive treatment. A soil survey of a white land area north of Salem disclosed the fact that 39 percent of the area was typical white land, 36 percent loam, and the remainder an intermediate phase.

Chemical analyses show a uniformly good total supply of potash and phosphorus with only a moderate amount of nitrogen or active humus.

A sample of white land collected a short distance north of Corvallis was analysed by Mr. E. J. Carpenter under direction of the Station chemist, Prof. H. V. Tartar. The composition of the soil was found to be as indicated in Table II.

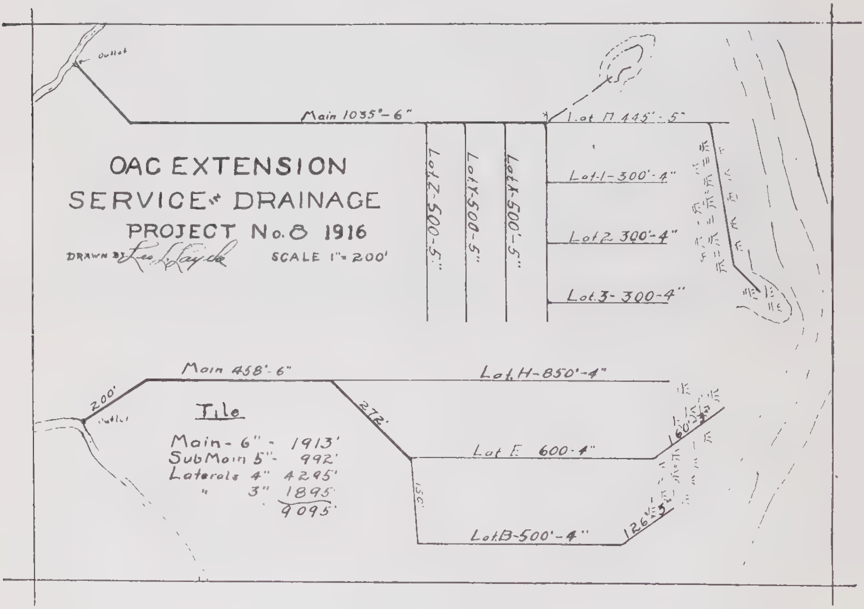

Fig. 3. Plan of drainage system. (Proj. 8, 1916.)

TABLE II. CHEMICAL ANALYSIS OF WHITE LAND

Moisture	3.68
Volatile matter	4.15
Nitrogen	0.10
Phosphorus (P_2O_5)	0.15
Lime (CaO)	1.43
Magnesia (MgO)	0.22
Potash (K_2O)	2.18

Professor Tartar found the lime requirement to be 1124 pounds of ground limestone to each acre foot, and the nitrogen content rather low.

The reaction of this soil being acid, liming is beneficial. Experiments of several years have worked out with a fair degree of definiteness the methods to follow whereby successful drainage, which is the key to improvement of this soil, may be accomplished. Reclamation of this type is given special attention later.

Peat and muck form the main body of the more important marshes. These organic soils are light in weight and very porous. "Beaver dam" is a local name for peat soil and explains its origin in places in the Willamette Valley. Variations in respect to depth and amount of inorganic materials are important points in the drainage of these soils. Deep peat occupies the central part of marshes and is frequently formed from a rank growth of tules or marsh grass. Such soils respond readily to drainage. Shallow peat may be underlaid with silt or clay, making it less attractive and more difficult to drain. Wire-grass, sedges, and flags commonly grow on such land. Where there is fair depth of partly decomposed vegetation mixed with mineral material, forming a muck soil, thorough drainage may be necessary for complete reclamation. Such soils are likely to be better balanced in plant-food supply and generally justify reasonable expenditures for drainage. The vegetation on such muck soils is frequently grasses, mint, and rushes. Chemically, these soils in Oregon usually have an acid reaction and the mineral elements may be lower than average so they may respond to treatment with lime, manure, or potash. Such soils are rich in nitrogen and humus and, when drained, can generally be made very productive. The greater part of the marshland on the coast is fresh-water marsh near stream outlets. A soil survey of Warner Valley* made by the major author for the Reclamation Service discusses drainage conditions in a typical area of this

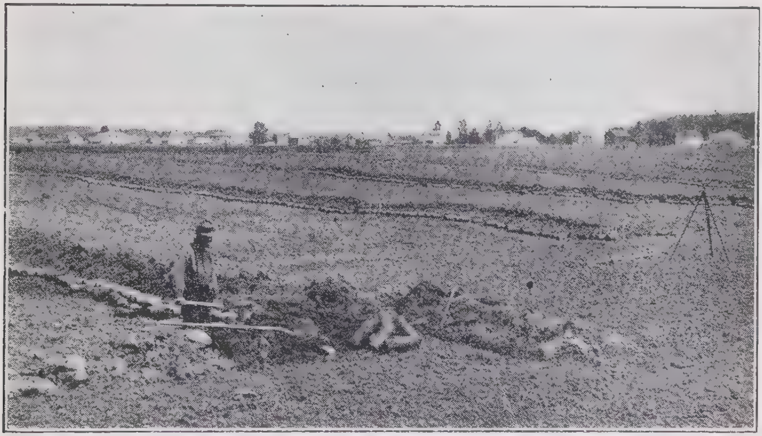

Fig. 4. View of laterals, Oregon Experiment Station.

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*Whistler, J. T., and Lewis, J. H. Warner Valley Rept. Ore. Co-op. Works, U. S. Reclamation Service, 1916.

land. Considerable drainage development is taking place in the peat soils of the State.

Alkali soils occur in the native state or develop from irrigation due to accumulation of weathered soluble salts by evaporation of soil moisture at the surface. The chief remedy for arid soils so affected is drainage, as it affords a means of washing these salts down and out of the soil. The texture of alkali soils ranges from light loam to heavy clay loam. The former type usually bears mixed sage and salt grass or some greasewood (Atriplex). Where underlaid with porus layers a few feet from the surface these soils are drainable.

The heavier soils may be flushed off where outlets are close at hand, but at higher altitudes these greasewood lands are often too heavy, rough, and alkaline to be very attractive for reclamation purposes at present. Drainage of typical areas of alkali lands are fully discussed by the writer in soil surveys of the Ochoco*, Silver Lake* and Malheur* projects.

Soil Water. The soil water dealt with in drainage is the free water which moves by gravity to lower levels or fills the larger pore spaces, causing soil to be water-logged. Most field crops do not flourish with their roots in saturated soil. If this water is kept moving or is "live water" and contains some air, crops can tolerate it more or less in the free state. If the water table is near the surface indefinitely the plant roots will not grow into it or, if the water table rises near the surface, the plant roots already in the subsoil will be rotted off. In a wet climate, excess water comes from the sky more directly, while in irrigated lands, it has been stored and seeps off through gravelly strata, damaging the low lands. In drainage, we must deal with excess rather than average rainfall.

The rate of flow of soil water depends mainly on the head or gradient, relative porosity of soil, and temperature. In Table III, summarized from United States Geological Survey data, the velocity of flow is based on a fall or grade of 100 feet to the mile, a porosity of 32 percent, and temperature 50 degrees F.

TABLE III. RATE OF FLOW OF SEEPAGE WATER AS AFFECTED BY SOIL TEXTURE

Kind of soil	Diameter of soil grains	Velocity In feet per day	Velocity In mi. per pr.
	mm.	ft.	mi.
Very fine sand	0.01	0.0038	0.00026
Fine sand	0.05	0.0923	0.00638
Medium sand	0.10	0.3690	0.02551
Coarse sand	0.25	2.3050	0.1594
Fine gravel	0.50	9.2240	0.6377
Silt	1.00	36.9000	2.551

Usable Soil Moisture. The soil moisture which is usable by plants is mainly in capillary form. Wet soil may dry and bake quickly after rain, for in its water-logged condition there is a minimum amount of pore space, and such a soil does not retain moisture well in time of drought. In the wet soil, cementing materials which should hold the soil particles in clusters are dissolved; the film attraction being eliminated the soil structure is broken down and the pore space reduced. Drainage removes the

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*Whistler, J. T., and Lewis, J. H. Ochoco Rept., Silver Lake and Malheur Rpts., Oregon Co-op. Work, U, S, Reclamation Service,1915.

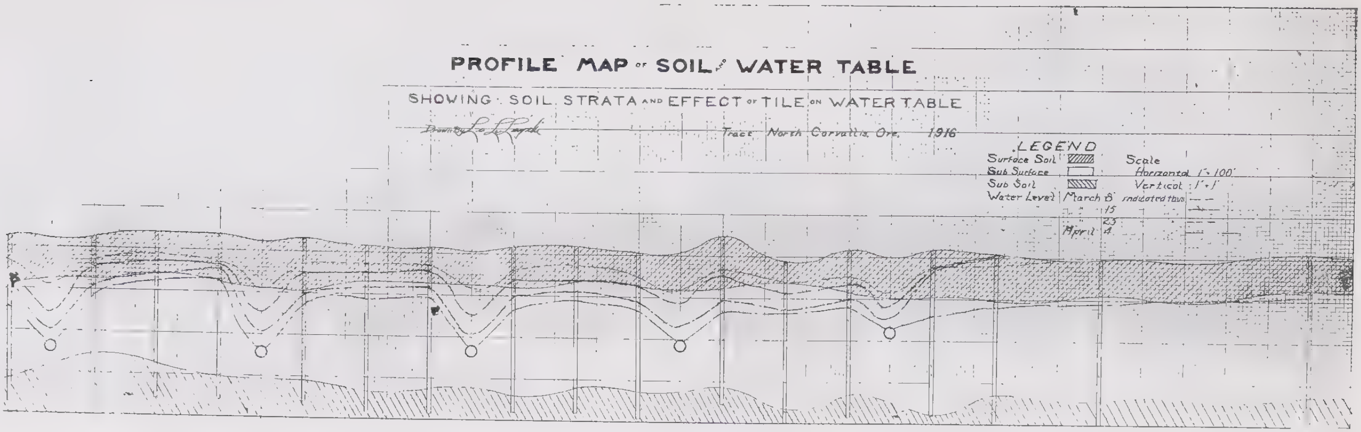
PROFILE MAP OF SOIL AND WATER TABLE
SHOWING · SOIL STRATA AND EFFECT OF TILE ON WATER TABLE
Drawn by
Tract North Corvallis, Ore. 1916
LEGEND
Surface Soil ▨
Sub Surface ☐
Sub Soil ▧
Water Level March 8 indicated thus
15
23
April 4
Scale
Horizontal 1"=100'
Vertical 1"=1'

Fig. 5. Water table in drained vs. undrained white land.

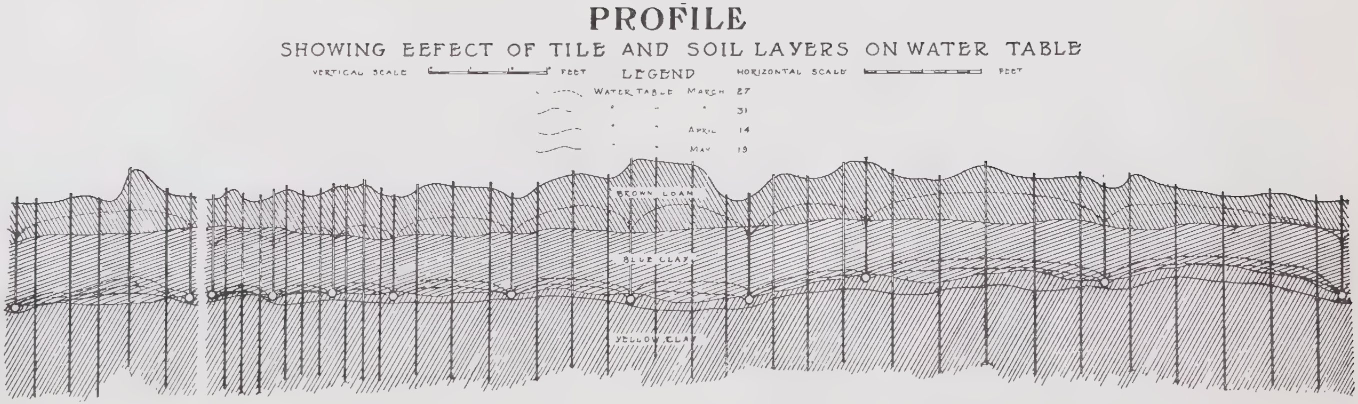

Fig. 6. Typical section of white land showing effect of tile on water table.

excess water and makes room for more usable moisture. Excess water finds its way to the tile drains through the line of least resistance in the soil and enters between the ends or "joints." This process of drainage does not leave the soil without moisture but simply removes the excess and makes room for more usable moisture and some air. The tile simply remove the gravity water to a level below the root zone, and from this level capillary water may be supplied to the soil above. It is therefore practically impossible to overdrain a soil, since capillary water is not affected by drainage except as to the distance it must rise.

Benefits of Drainage. The primary object of drainage is to remove the excess water. (1) This enables crops to root deeper, and a larger soil layer is thereby provided in which to store usable or capillary soil moisture. (2) This deep rooting and improved moisture condition cause the soil to become more mellow and friable. The soil is then cultivated with less difficulty and expense. (3) Drainage encourages aeration by emptying the pore spaces which are filled with water, thus making room for soil air. The presence of air in a drained soil aids decay, nitrification, and the liberation of plant food. (4) Drainage makes the soil warmer because moisture which would otherwise evaporate from the surface and chill the soil moves off through the drains. (5) The soil is dried out earlier in the spring, enabling the farmer to plant his crop earlier with a corresponding increase in the length of the growing season. (6) It prevents erosion by making the soil more absorptive. Each foot of fairly dry soil will absorb from one to three inches of water when given time, which greatly reduces surface run-off. (7) Drainage prevents the heaving or freezing out of the clover and grain on wet land. (8) Drainage prevents the rise of alkali on irrigated land. (9) In addition, drainage improves sanitary conditions and aids transportation and highway improvement and general development of the country. Timely drainage increases crop yields and land values and is one of the most permanent improvements that can be put on land.

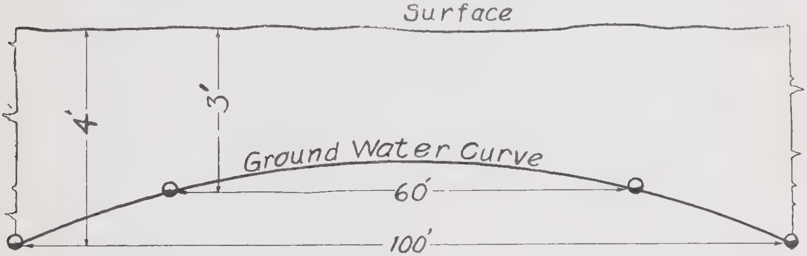

Fig. 7. Section showing relation of depth to distance.

II. TYPES OF DRAINS AND THEIR LOCATION

Definition of Parts. A single line or string of tile has an upper end or head and a lower end or outlet. The finished tile base at each hub stake or station is called the grade; the slope of this line, usually expressed in fall for each hundred feet, is the gradient. A drainage system will have a main, or a line of large tile which serves mainly as a conducting drain and which receives the discharge from sub-mains and laterals. The laterals are usually single lines serving mainly as collecting drains and they are frequently arranged in parallel systems.

Permanent shallow open ditches or surface runs in the field should be made to follow fences or direct lines as much as possible. They may be kept in grass and be used to remove the flood water in case of extremely heavy storms, after which underdrains will remove the excess water from the subsoil.

Intercepting or cut-off drains are drains laid at the base of a slope to collect the water that the heavier subsoil layers are carrying onto the flat land. More frequent use of this feature is advisable; it is better to keep the water off the land than to suffer the damage.

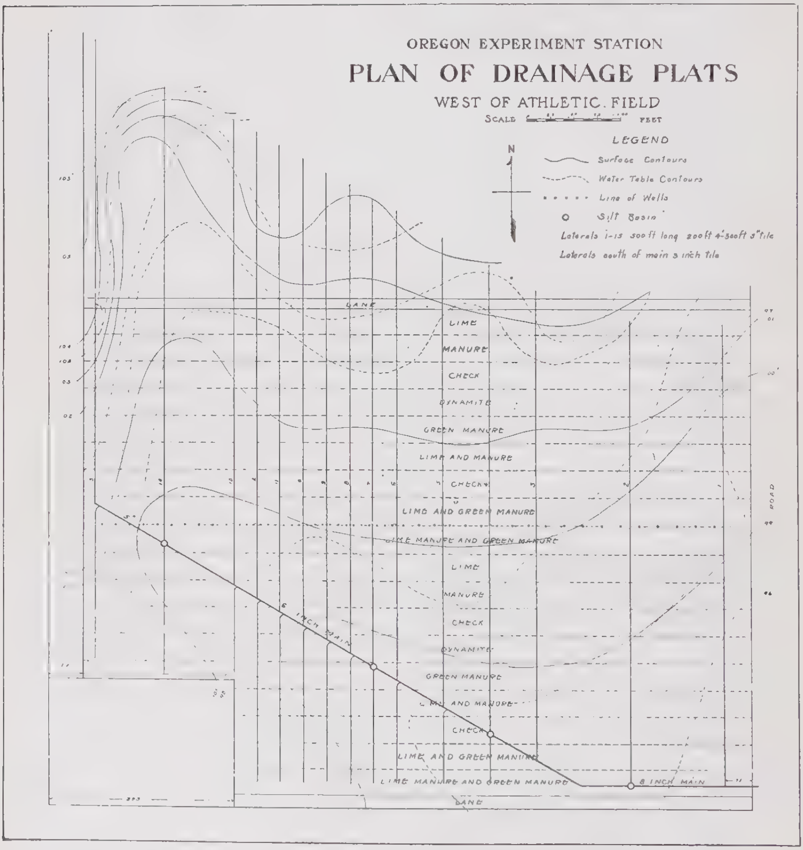

Fig. 8. Plan of drainage plots, Oregon Experiment Station.

Open ditches might be made for outlets where a large volume of water is to be handled, but there are several very serious objections to them and their use is to be avoided wherever possible.

Types of Drainage Systems. For ordinary field crops on undulating land, natural or random systems of drains are used following the natural depressions of the land and diverging like the frame of a tree. **Parallel systems** are well adapted to the drainage of flat-lying land situated with a gentle slope in one plane. Long parallel laterals give the least amount of double drainage with less expense for junctions and large tile. It is often convenient to have the laterals run parallel to the fence lines and to the dead furrows so that supplemental surface drains can be provided, and the land given a slight slope toward the drains. **Vertical drainage** is only practical where there is wet land with a tight subsoil and then a coarse layer underneath through which water will pass. A vertical drain can be made of small wells, lined with a column of drain tile surrounded with gravel, and covered below reach of the plow, making a permanent passageway down through the impervious layers. See Fig. 30.

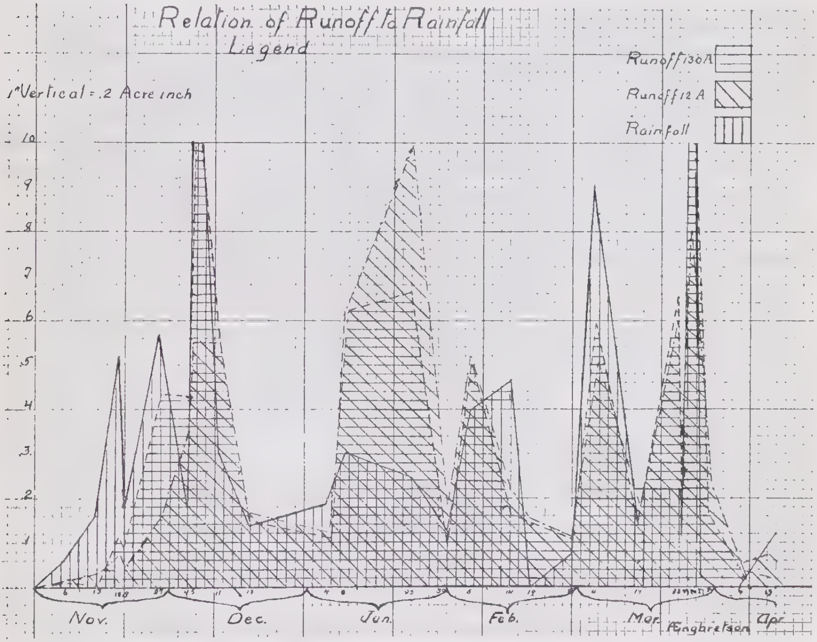

Fig. 9. Hydrograph showing mean daily rainfall and outflow, Experiment drains.

The Location of Drains. A complete drainage system for the whole farm should be tentatively planned, at least a complete system for the watershed considered. It may be installed in units as time and means permit and can be developed so as to afford more thorough drainage as general economic conditions come to justify a higher state of improvement.

In locating drains, best authorities consider it good practice to lay the main in the line of natural drainage where the water collects; for the surface and subsurface strata will convey the water to these depressions. On our flat lands, the laterals should run in the line of greatest slope; and long, parallel laterals should be used where possible. The tile lines should be run straight or with gradual curves. This makes them easier to construct; easier to locate in later years; is an actual saving in tile and labor and increases the capacity of the tile by reducing friction. The drain system should be planned to reach the source of excess water and convey it away as directly as possible. Plans should be made to handle a maximum amount of water with a minimum number of tile, so as to get the highest possible efficiency out of every hundred feet of tile employed.

An experienced drainage engineer may add five percent to the cost and as much as fifty percent to the efficiency of a system.

Preliminary Studies. When planning a drainage system begin at the outlet and determine, by use of the level, the depth the drain can be placed and have a free discharge. All leveling data should be referred to a permanent bench mark. Make test pits with a post hole auger or soil auger at frequent intervals as the examination proceeds upstream and observe the character of the subsoil to determine how deep to put the drain so it will be in the most free-working soil. (See Figs. 8 and 14.) The occurrence of underground water can be noted and any seepage water traced to its source to determine whether it appears under or over any hard layers of soil. The drains can then be designed to intercept and convey this water away as directly as possible. A few range poles or lath should be set at points in the field through which it is desired to have the survey for the drains pass. A preliminary survey may be made to decide on the best possible outlet and determine the lay of the land. A series of level readings taken across the field in both directions or around the field will usually disclose variations in nearly flat areas. A contour map of a wet farm having irregular topography would be very desirable in planning the system.

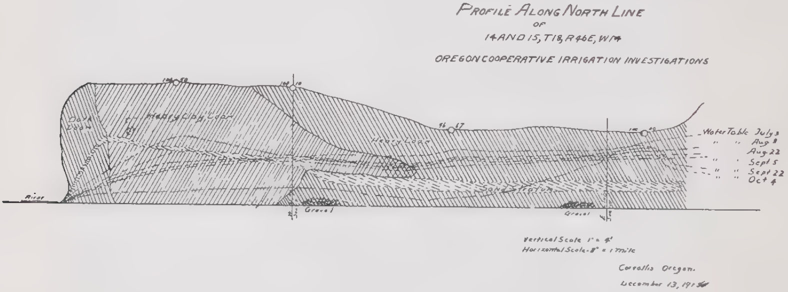

Fig. 10. Profile of alkali soil and water tables, Malheur Valley.

Because drainage is a rather expensive improvement and some soils, like the white land, are rather slow to respond to drainage, it is necessary that we locate our drains so as to facilitate the entrance of water into the tile in order to make the drainage enterprise thoroughly profitable and successful.

III. DEPTH AND DISTANCE APART FOR TILE

Relation of Depth to Distance. In a uniform porous soil, greater depth will permit greater distance apart. In such a soil suppose a 4-foot depth would permit a distance of 100 feet apart. If the depth is decreased to 3 feet, the distance would have to be decreased to approximately 60 feet as shown in Fig. 9, so as to lower the water table to the same depth at its highest point between the lines. This is the principle to bear in mind in designing depth and distance, where either depth or distance is limited by the factors discussed hereafter.

Factors Affecting Depth and Distance. (1) The character of the soil and subsoil is perhaps the most influential factor affecting depth and distance apart. It is evident from previous discussion that water moves more slowly through the heavier soil and it must not be required to move as far. A closer spacing is necessary and with it economy demands less depth. The presence of impervious layers as already described makes it necessary to place the tile above or below this stratum depending on the location of the water.

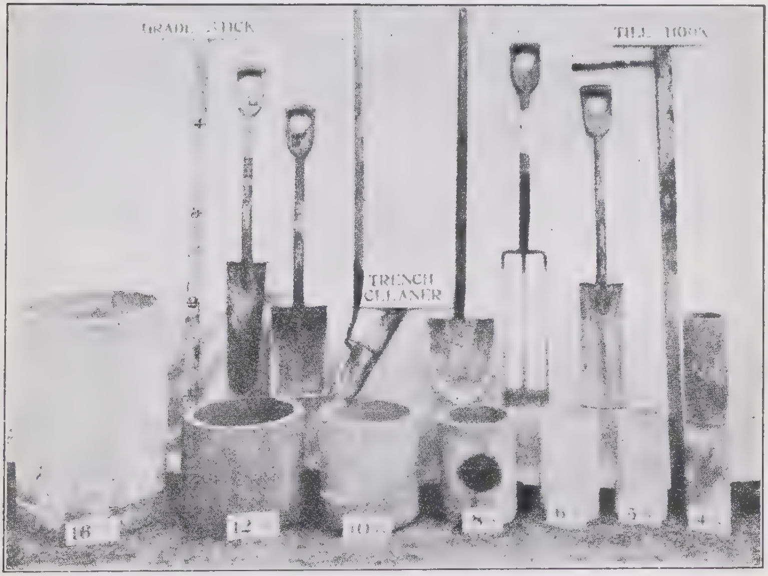

Fig. 11. Tile-laying tools and samples of tile. (Courtesy Wisconsin Experiment Station.)

(2) The amount and distribution of rainfall during the growing season determines how much water is to be removed. Large amounts of water require more access to drains.

(3) The nature of the crop to be grown may affect the depth for drains. Grasses and other shallow rooted or water-loving plants do not require deep drainage. Corn and other grain crops require more protection. Legumes like alfalfa and clovers need good deep drains.

(4) Depth of outlet may limit the depth of drains. This frequently is the case in tide lands and occasionally in flat areas in the Willamette Valley.

Experiments Relating to Depth and Distance. Numerous experiments have been conducted to determine suitable depth and distance apart for tile.

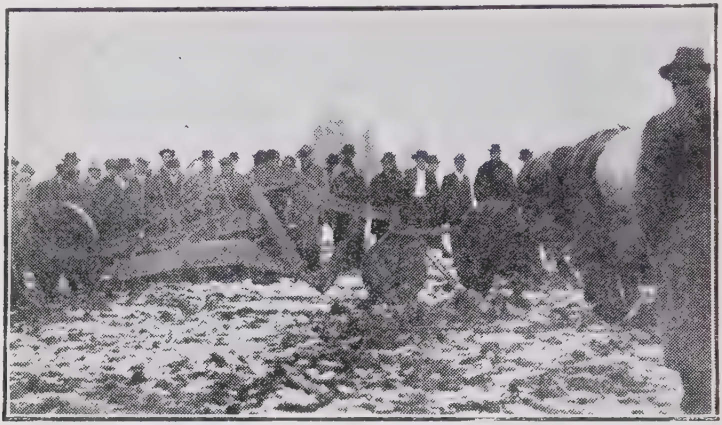

Fig. 12. Cyclone ditcher.

A series of laterals, 60 feet apart and from 2½ to 4½ feet in depth were installed in white land near Albany in 1908 by the United States

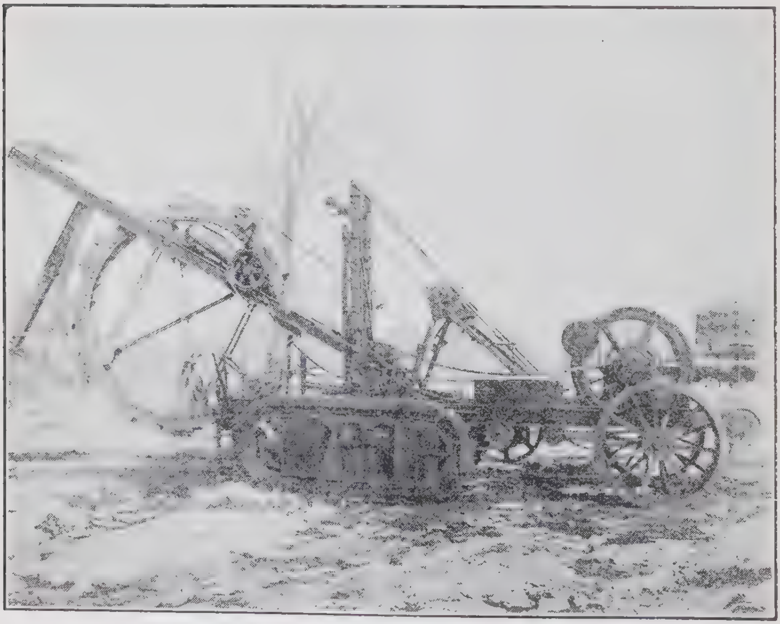

Fig. 13. Buckeye trencher.

Office of Drainage Investigations. Observations have indicated that no advantage has been derived from the deeper tile. A study of the water table indicated that for two days after heavy precipitation, the deeper drains were less effective than those laid 33 to 36 inches deep. This is probably due to the fact that the most pervious stratum in the white land section occurs at 33 to 36 inches.

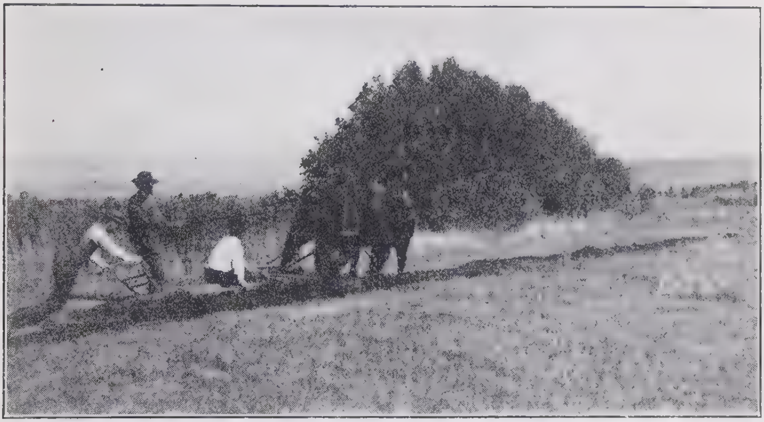

Fig. 14. Starting a ditch in tough sod.

The Oregon Experiment Station installed an experimental tile system on white land at Corvallis. All laterals were laid 33 to 36 inches deep and in four series of 25, 50, 75, and 100 feet apart. The results given in Table IV show that the greatest efficiency was obtained by the 50-foot spacing. Although a greater yield was obtained by the 25-foot spacing the cost of drainage was twice as much.

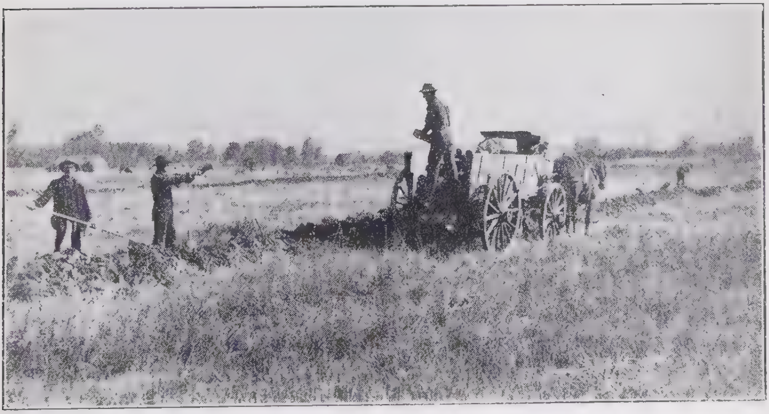

Fig. 15. Hauling and distributing tile.

TABLE IV. DISCHARGE FROM LATERALS PLACED DIFFERENT DISTANCES APART. WINTER 1915-16.

Distance between laterals	Maximum discharge in acre in. an acre in 24 hr.	Mean discharge in acre in. an acre in 24 hr.	Mean daily rain previous two days	Daily outflow	Feet of tile per acre	Mean acre in. discharge per 1000 ft. tile in 24 hr.	Yield barley per acre 1915
			in.	percent			bu.
25 ft.	1.20	.48	0.60	80	1742	.96	33.73
50 ft.	1.35	.55	0.60	92	872	1.10	29.90
75 ft.	.80	.33	0.60	55	586	.66	27.90
100 ft.	.90	.32	0.60	53	436	.64	20.35

TABLE V. ACRES SERVED BY TILE OF VARIOUS SIZES AND SLOPES WHERE ONE-HALF INCH OF WATER IS TO BE REMOVED IN 24 HOURS—BASED ON KUTTER'S FORMULA, N=.015, R=.5

Grade	.05	.1	.15	.20	.25	.30	.4	.5	.6	.7	.8	1.0	1.5	2
4 inches	....	1.5	2	3	3.3	3.5	3.8	4.2	4.6	5	5.4	6.5	7.3	9
5 inches	2	3	4.1	4.8	5.2	6	7	7.3	8	9	9.6	11	13.7	15.5
6 inches	4	5.8	7	8	9.2	10.5	12	13.5	14.5	16	17	18.5	24	27
7 inches	6	9	11.2	12.5	14	16	17.5	20	22.5	24	25.8	29	36	41
8 inches	8.5	12.5	16	18	20	22	26	30	32	35	38	42	51	61
10 inches	17	24	30	35	39	42	48	55	61	66	70	80	97	112
12 inches	28	41	50	58	65	72	84	90	104	110	116	133	163	190
15 inches	53	76	92	107	121	135	155	175	190	206	220	250	303	355
18 inches	88	125	152	178	203	220	260	285	310	338	365	400	500	575
20 inches	115	170	210	242	275	298	345	384	425	462	500	550	670	780
22 inches	153	215	265	305	345	380	425	490	535	575	615	690	850	1000
24 inches	205	285	355	404	460	496	568	640	700	750	810	910	1110	1315
26 inches	250	350	425	500	550	610	700	775	850	930	1000	1100	1400	1610

Winter barley under similar conditions except on undrained land produced about 16 bushels an acre.

An experimental tile system installed in tide land at the branch experimental station near Astoria, has been previously described.* In this system series of laterals were arranged at 50-, 75-, and 100-foot intervals. With the greater spacing a greater depth was used, the depth ranging from 3 to 4 feet. Observations have been made by Station Superintendent Engbretsen of water-table outflow and yields. Results have indicated that the 4-foot depth and 80-foot spacing gave adequate drainage where that depth of outlet could be secured. Where only 3-foot depth of outlet is available a 50-foot spacing is recommended.

Conclusions Regarding Depth and Distance. Experiments with heavy soils of the Dayton Series or white lands indicate that a depth of about 36 inches and a distance of 60 to 66 feet is the best practice. A closer spacing will doubtless give increased yields, though even a wider spacing is profitable. The soils classed in soil survey work as Amity are somewhat less difficult to drain and will be drained by lines 36 to 40 inches deep and 80 feet apart. They range from white land, described above, to the brown loam soils of the valley benches, which are often improved by drainage at a depth of 42 inches and a distance of about 100 feet. In this brown soil tile lines can frequently be arranged in a natural or random system following up the swales and depressions.

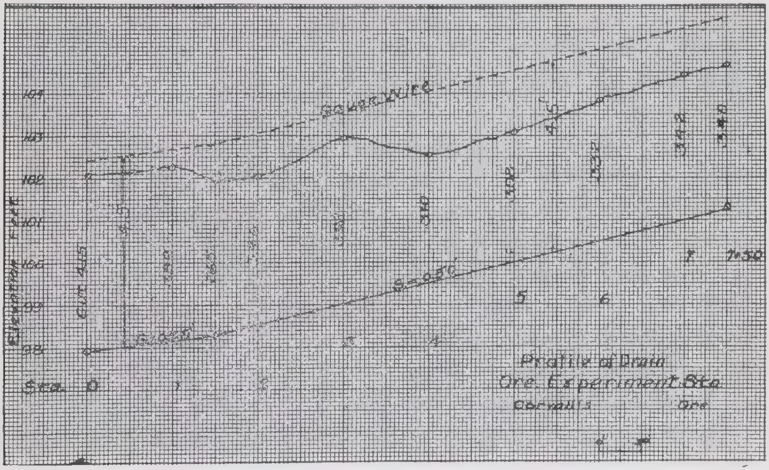

Fig. 16. Profile of main drain, Experiment Station Plots.

Black clay or "black sticky" is best drained by use of intercepting or foothill ditches, and an outlet drain and surfacing and perhaps inlets.

The new valley fillings along the small streams in Western Oregon classed as loam to clay loam need drainage, and, in this work, the foothill or intercepting drain is an important feature just as it is in drainage of seeped hill lands with mottled subsoils.

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*Powers, W. L. The Improvement of Marsh Lands in Western Oregon. Ore. Agr. Col. Exp. Sta. Bul. 157, 1919.

Tide land at the branch experiment station at Astoria has been effectively drained by tile placed 80 feet apart and 4 feet deep.

In these lands the depth may be limited to the depth of outlet obtainable.

Peat soil used for onions and other intensive crops will justify drainage lines at 50-foot intervals and 4 feet deep, although for ordinary field crops temporary drains in these lands may be open ditches 200 to 300 feet apart and 5-feet deep.* Such soils are subject to shrinkage and require deeper drainage to allow for this.

In humid sections the mistake is more commonly made of putting drains too far apart or too shallow than otherwise.

The drainage of irrigated land is a matter of intercepting seepage water and of lowering the water table in the whole locality. It is necessary to get the tile in the most porous or water-bearing strata, which may occur at a depth of 7 to 10 feet. The aim should be to lower the water table below the capillary limit of the soil, or say 5 feet below the surface at the highest point so that alkali will not be drawn to the surface. The distance will depend on the topography and soil and subsoil conditions and may be 20 to 80 rods apart in such sections as Malheur Valley and 9 feet deep. The drains must be placed where they will effectively catch the out-cropping water; the relief well (Fig. 33) may be necessary to bring the water up to within reach of a tile line. Where thick impervious chalk subsoil occurs as in Klamath Basin it may be necessary to use deep intercepting drains as far as possible and then closer spacing with lines on the hard-pan.

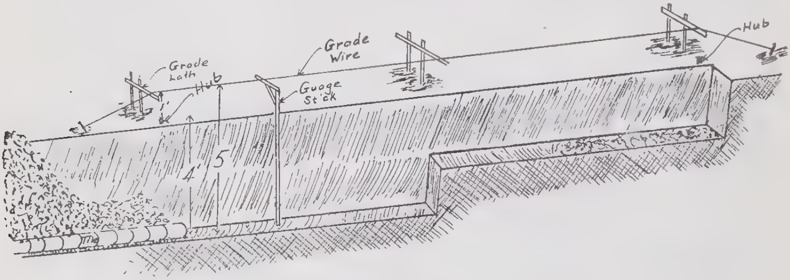

Fig. 17. Perspective sketch showing use of grade lath.

IV. CAPACITY FOR DRAINS

The capacity of drains refers to the amount of water they will discharge and in effect how much land a certain drain will serve. The chief factors affecting tile capacity are (1) grade, (2) size, and (3) roughness.

Grade for Drains. Grade, although not absolutely fixed, is limited by the topography or slope of the land. The question most frequently asked by farmers is, How little grade can be used? The answer is, As little as .05 foot per 100 feet for large tile. But care must be exercised that drains with no fall are carefully laid to grade. It is more econnomical to obtain more grade even at the expense of deep cuts. A good average grade obtainable is about .1 foot per 100 feet for mains and .2 foot or more for laterals.

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*Powers, W. L., and Johnston, W. W., The Improvement and Irrigation Requirement of Wild Meadow and Tule Land. Ore. Agr. Col. Exp. Sta. Bul. No. 167, 1920.

Grade is a very important factor in fixing capacity. Capacity is almost directly proportional to the grade and varies as the square root of the grade. For example, a drain with a grade of .1 foot per hundred has just half the capacity of a drain with a grade of .4 foot per hundred. The latter drain will serve approximately twice the area as the tile with .1 grade. Economical drainage design will therefore demand all the fall that can be obtained on land requiring drainage. There is very little danger of too much fall.

Size for Drains. The size of a drain is the inside diameter in inches. It is the last thing to be determined in drainage design. Size is determined by the following factors. (1) Slope of the drain, as already explained. (2) The size of the area each drain has to serve. (3) The drainage coefficient, or the depth of water to be removed; technically defined as the depth of water, in inches, over the area to be removed per 24 hours. This coefficient must be large enough to give the degree of drainage required; i. e., large enough to care for the heaviest rain that probably will occur in the farming season. Insufficient drainage may be due to lack of sufficient drainage coefficient. Drainage coefficient is determined by a consideration of factors of which the following are the more important:

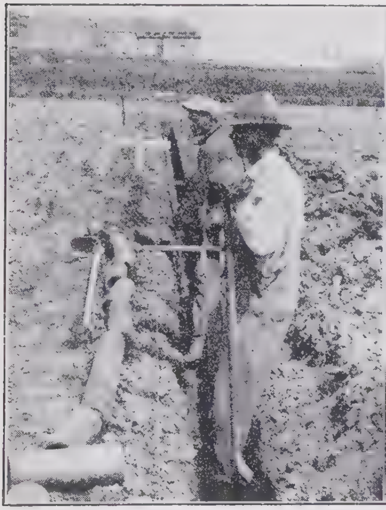

Fig. 18. Finishing trench and laying tile, Oregon Experiment Station.

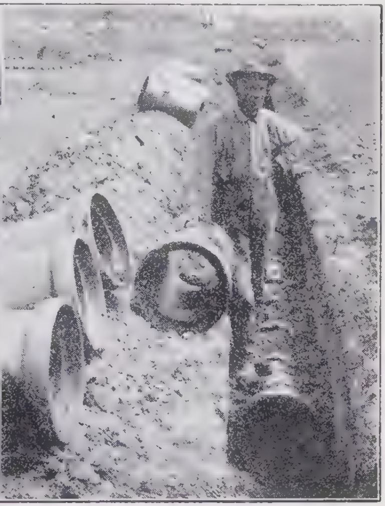

Fig. 19. Laying large main drain, Oregon Experiment Station.

(a) Rainfall, its amount, intensity and seasonal distribution. Consider the amount of rainfall that occurs during the season of cultural operations.

(b) Soil exerts considerable influence on the run-off coefficient. Under proper conditions of drainage tilth and crops a soil will absorb from 1 to 3 inches of rain providing it has had sufficient time to rid itself of the previous rain.

(c) Slope of the underdrained area may be such as to hasten surface run-off before the water has had time to percolate into the tile. Gentle rains permit more absorption if under-drainage is afforded.

(d) Frequent spacing of laterals affords more access to drains and a larger maximum outflow would be expected from a given area. The outflow coefficients recommended for different conditions are: For Dayton and Amity soils and other low-lying flat land of the Willamette Valley, ⅓ to ½ inch. For coast sections the coefficient may vary from ¾ to 1 inch, depending on the rainfall of the locality. For irrigated lands the coefficient must be sufficient to include all the seepage water that is likely to reach the drain. Since there may be a large yield in parts of the field, drains of ample size will be economical and usually should be sufficient to handle 1/6 to ¼-inch coefficient.

Roughness. Roughness in a tile line may reduce the capacity of the line considerably. For this reason ill-shaped tile should be rejected, the tile should be carefully abutted, and the line run as straight as possible.

Computing Size of Drains. For computing the size of drains three factors must be determined in each case: (1) the size of the area to be served by the drain, (2) the slope of the drain as determined by the survey, and (3) the drainage coefficient described above. Use of Kutter's modification of the Chazy formula is recommended for computing the size of drains, especially for the sizes ranging from 6 inches upward. It follows:

$$v = \left\{ \frac{41.66 + \frac{.00281}{s} + \frac{1.811}{n}}{1 + \left(41.66 + \frac{.00281}{s}\right) \frac{n}{\sqrt{r}}} \right\} \sqrt{rs}$$

In which v=the velocity of flow in feet per second.
s=the slope or fall in feet per foot.
n=the coefficient of roughness.
4=hydraulic radius in feet=the cross-section area of stream divided by the wet perimeter.

The solution of this formula will appear difficult to those unaccustomed to the work, yet it is the simplest form in which it can be used. For this reason Table V (page 20) is submitted, which is based on this formula and which is sufficient for farm drains. Interpolations for any size and grade within the range can be made between sizes and grades with sufficient accuracy.

Though there are many other formulas in use for determining draintile capacities, Kutter's formula gives a lower capacity than any of the others, which is good assurance that it is a safe formula to use. Elliott's formula* gives much larger values for the smaller tile and somewhat larger for the larger tile. Recent elaborate investigations* have resulted in the development of an experimental formula, which also gives larger values.

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*C. G. Elliott, Engineering for Land Drainage 1919 Ed. P. 1010.

The experiments of recent investigators indicate that the acreage given in Table V might be increased by 50 percent for the 4- and 5-inch tile.

V. PROCURING TILE

After sufficient data have been gathered to inform the farmer how much tile and what sizes are needed, a tile bill should be prepared. The bill should include all specials, such as "Y's" for making junctions and vitrified sewer pipe for outlets, if these are deemed necessary to protect from frost.

Clay tile should be well burned, cylindrical, and straight. An unbroken tile will give a characteristic ring when struck with a piece of metal. Since clay shrinks on burning, over-burned tile will be smaller in dimensions. Good tile are durable, easily laid, and last indefinitely under proper conditions.

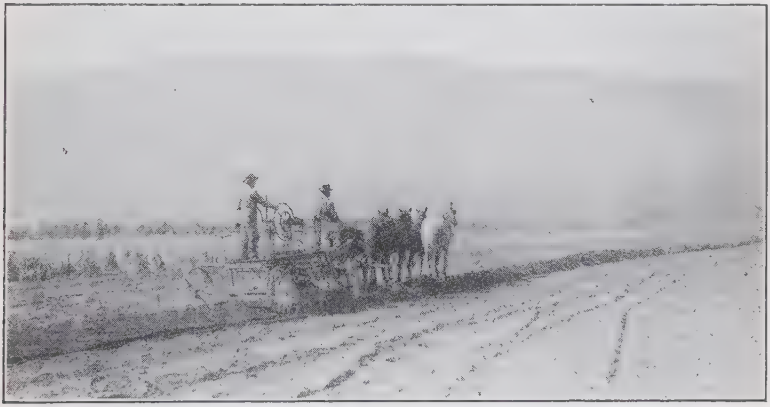

Fig. 20. Filling tile ditch with road grader.

There is generally a slight curve or hump in clay tile which can be used advantageously in making slight turns in a line of tile; or if this humped side is placed up the top edges of the tiles will fit close together.

Concrete tile have come to be used extensively for drainage purposes during the last decade. They have an advantage where good clay is not obtainable. Concrete tile should be made of a proper mixture, machine tamped, and carefully cured. The wet-mixture process is preferred and larger sizes should be reinforced. Dense tile of rich mixture are more resistant to alkali.

Clay or concrete Tile. Almost any advantage of either material over the other may be offset by nearness to consumer. The chief differences are: Concrete tile are somewhat subject to disintegration in sections where alkali is present. There is less chance of deterioration where made very dense and of good material. Concrete tile are somewhat heavier than clay tile of the same size, which makes for a higher freight rate. Concrete tile will improve in strength with age. Concrete tile are slightly more uniform, since clay tiles shrink and become slightly irregular during burning. All tile seriously defective should be rejected at the factory; reliable manufacturers cull their product properly.

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*Yarnell, D. L. and Woodward, S. M. The Flow of Water in Drain Tile, U. S. Dept, of Agric., Bul. 854.

Specifications for Tile. The tile bill should not only contain the sizes and number of tiles wanted but some agreement must be included by which to reject bad material. If there is any choice as to materials from which tile are made it should be stated in the order.

For the purpose of standardizing requirements of all such materials, a society known as the American Society for Testing Materials, composed of specialists and manufacturers, has compiled "Standard Specifications for Drain Tile."* in which are set forth definite methods of testing for several characteristics and the requirements to be met in each. Three classes of drain tile are provided for: (1) Farm Drain Tile, for ordinary private drainage work on farms for moderate-sizes and depths. (2) Standard Drain Tile, for ordinary district drainage. (3) Extra Quality Drain Tile, where an extra quality is required.

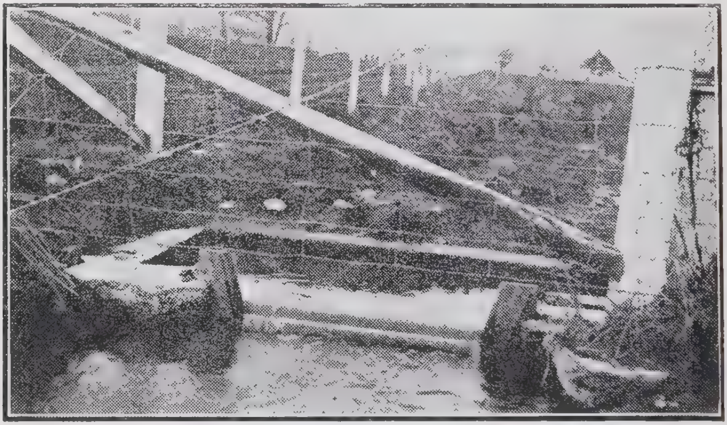

Fig. 21. Outlet and wier.

The first class is sufficient for ordinary farm drainage as described in this bulletin except where the greater depths are recommended. In this case the better grade of tile (Extra Quality) should be specified. The following statement attached to the order should bind the seller and protect the purchaser and is only fair to both.

> "This order shall include only such tile as meet the specifications and physical requirements set forth by the American Society for Testing Materials, serial designation C4-16 for drain tile of the class of Farm Drain Tile (or other of the three classes as desired)."

This throws the responsibility onto the man who has the best opportunity to know the quality of the material in question.

The tile bill of sizes and quantity with the foregoing statement of quality can be submitted to reliable manufacturers for bids.

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*"American Society for Testing Materials" Standard Specifications for Drain Tile Serial No. C4-16.

VI. CONSTRUCTION OF UNDER-DRAINS

When to Tile. The best season of the year to drain wet lands in Western Oregon is from April up to July. Earlier than this, excess water and heavy rains will interfere and later in the season the soil becomes dry and hard so that it is more expensive to work. "Beaver dam" and marsh land will be least subject to excess water in later summer, while the irrigated land may contain less excess water in early spring before irrigation begins.

The Permanent Survey. While the entire drainage system should be planned before construction begins, it is useless to set grade stakes for more drains than can be installed during one season as these will be plowed out or tramped out by animals and will need to be replaced. Where the system is small and there is a fall greater than a foot to each hundred feet, the drains may be successfully laid by water grade, the amount of tile needed being estimated by chaining or carefully pacing out lines to be installed.

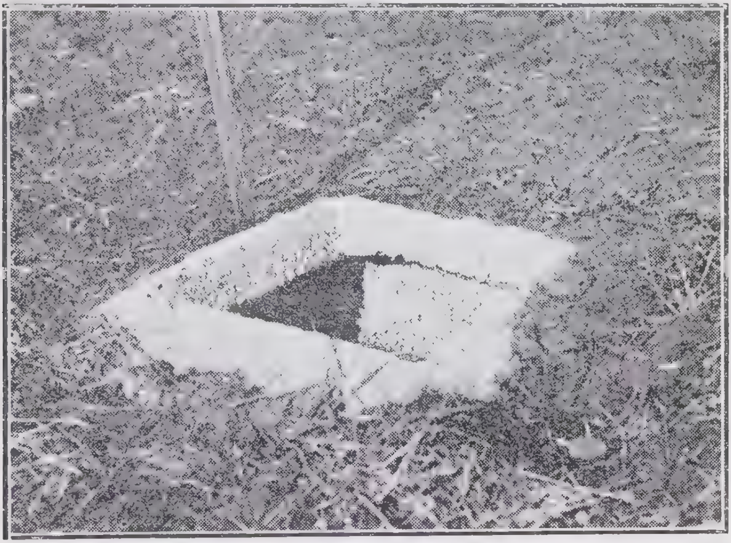

Fig. 22. Concrete silt basin.

After laying out the general plan of the system, hub stakes are driven at regular hundred- or fifty-foot intervals beginning at the outlet. These hub stakes should be about two inches square and twelve to eighteen inches in length, so as not to be easily disturbed. They are set in a line at the side of the proposed tile line, and driven flush with the ground. Guide or guard stakes are numbered according to the number of hundred feet from the end of the line or outlet; they are driven in front of the hub, leaning toward the head of the drain.

The survey gives the relative elevations of the hub stake, and a profile provided by the engineer will give the depth of cut below each hub.

While the data are fresh in mind or before the tile are hidden, a sketch should be made of the tile lines, showing their length, depth, and distance apart. A compass can be used to locate the bearings of different tile lines, and permanent landmarks such as trees and property corners should be referred to so that any part of the drain system can be located in after years. Maps may be simple but should be definite. A memorandum of the items of cost should be filed with this map.

Getting the Tile. The survey should determine accurately the number of feet of tile required for the units of the drain system which are to be immediately installed. After the size of the tile is decided upon for the different lines, a tile bill may be prepared and bids secured. If freight is involved the tile should be ordered in car-load lots and should be hauled directly from the car to the ditches, being distributed along the trenches within reach of the tiler when standing in the trench. (Fig. 20).

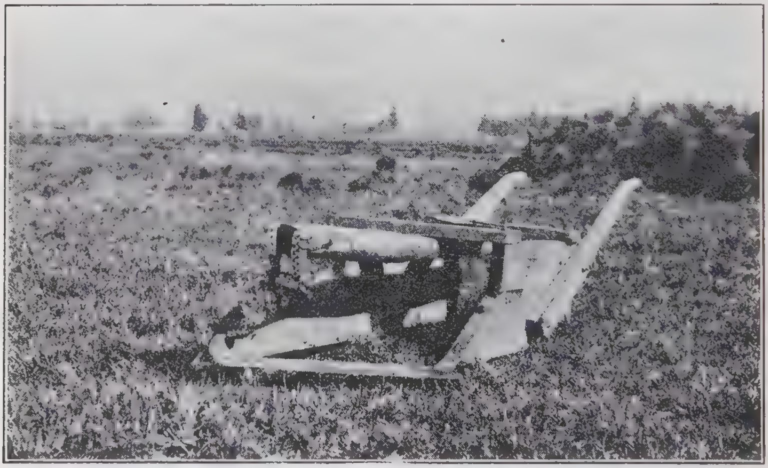

Fig. 23. Rush cutter.

Digging the Trench. Where there are many long parallel lines of tile to install, a trenching machine may be employed.* The wheel type of machine may be secured by a district or contractor. Where labor is scarce and where deep drainage is not required, horse-drawn ditchers may save money.

The use of the plow in starting the trench is favored only in tough sod where the work is done by unskilled hand labor. A trench 33 to 36 inches deep can be provided by removing two courses with the tile spade and should be started about eleven or twelve inches wide at the top.

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*Yarnell, D. L. Tile Trenching Machinery, U. S. Dept. of Agric., Farmers' Bulletin 1131, 1920.

In starting the ditch, a guide string is stretched on the ground at one side of the stakes. At bends a one-fourth-inch rope should be laid on the ground in a smooth curve. An eighteen-inch, square-pointed tile spade is commonly used for removing the first spading. The trench should be kept straight and the sides smooth and plumb. A good spademan will set the spade a little angling and will not need to trim the side of the trench much with a spade. A skilled worker will not leave much loose dirt in the bottom of the trench. Crumbs left in the trench should not be removed until the second spading is to be dug, if the weather is dry. A round-pointed shovel can be used to remove this loose dirt, after which the second spading is dug within an inch or so of the proposed grade. For removing the second spading, some workmen prefer a round-pointed tile spade, which makes the trench a little narrower at the bottom. The grade lines should be set before the second spading so that in no case will the ditch be cut below the proposed grade line. The last inch or two is taken out with a shovel and tile scoop, leaving a smooth, firm tile base rounded to support the tile.

Fig. 24. Oregon Agricultural College Experiment Station plots before draining.

The Use of the Grade Lath. In order to dig a trench to grade or with a finished straight tile base between the calculated grade points, it is best to use a gage line and gage stick, as shown in Fig. 20. The depth to dig at each station is calculated from the top of the hub stakes. Grade laths to carry the grade line are set over each hub stake at a uniform and convenient distance above the proposed tile base. A line is stretched over these grade laths and is a uniform distance above the proposed grade line and parallel to it. If the gage line is set four feet above grade the ditch should be trimmed out until a four-foot gage stick will just reach from the wire to the bottom of the trench when held in a vertical position. To set the grade lath at a proper height subtract the depth of the cut from the length of the gage. Grade laths may be set across the ditch or at one side with a cross arm extending out even with the near edge of the trench. A No. 18 gage galvanized wire makes a good gage wire, as it is light and strong as well as durable. In cutting through high ridges, a longer gage may be required. The gage wire must be kept tight.

Laying the Tile. Tile laying should start at the outlet and proceed up stream just as soon as the trench is finished to grade. A careful workman can be selected to handle the tile scoop and shovel just ahead of the tile layer. A tile scoop should leave a firm tile base and a little running water will help to make the tile base smooth. A carefully finished trench facilitates laying. The trench should be U-shaped at the bottom to give a supporting surface equal to about ¼ the circumference of the tile. The grade should be tested for every length of tile and the pieces should be placed in a straight line with the long side up so that the joints fit tightly at the top side and are nearly flush at the lower inside edge. An opening of one-eighth inch is allowable, but larger openings should be covered with fragments of broken tile called "bats." The tile may be rotated to fit, imperfections in the tile being taken advantage of in making slight turns. Ill-shaped, cracked, and broken pieces should be discarded. Where quicksand or muck causes a soft bottom in the trench, it is best to lay the tile on a board. Clay, burlap, or straw may be used to prevent quicksand entering the joints. Curves can be fitted by chipping off the inside edge of the tile carefully with a chisel and hammer. The Y's can be constructed, but it is best to order these when ordering the tile. Inspection of the drains before back filling should be made to see that no inferior pieces have been used, that there are no wide joints which appear unprotected, and that the tile are laid true to grade. If there is no running water, a level can be used to test the line at frequent intervals for dips or swells in the grade. If muddy water is encountered in the trench, it may be dammed up and held back until it can be passed through the tile in quantities sufficient to avoid

Fig. 25. Oregon Agricultural College Experiment Station plots after draining.

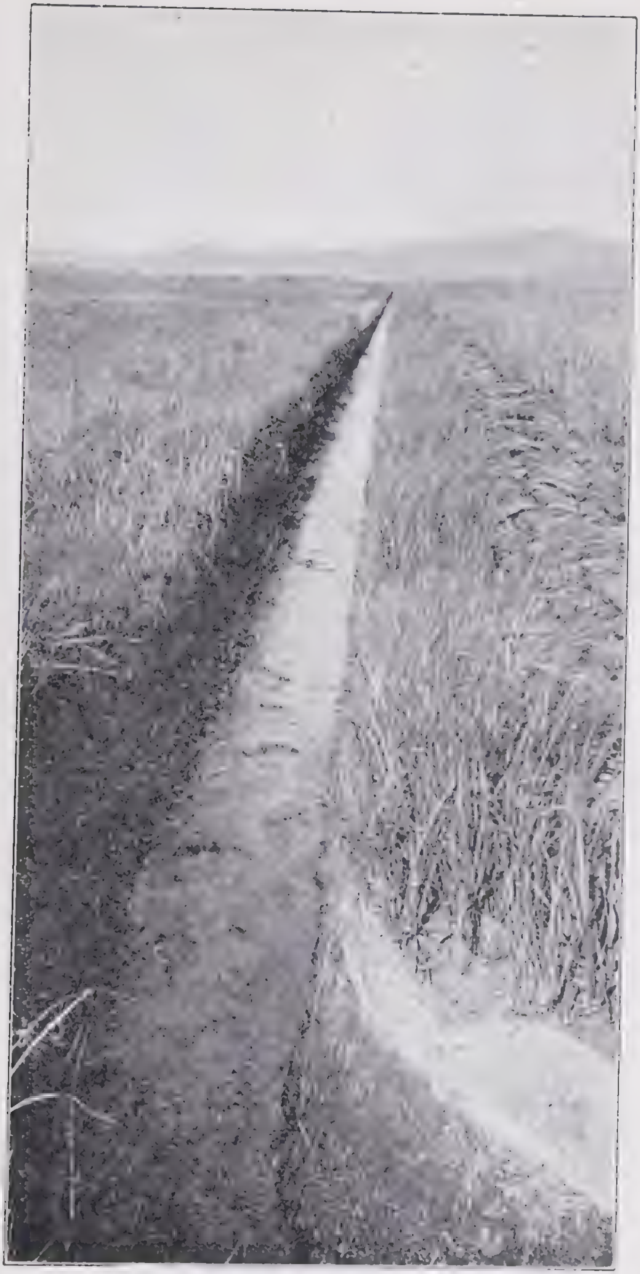


Fig. 26. Open laterals in peat, Clatskanie.

silting. Where the ditch banks are unstable, curbing may need to be used. The tile should be blinded in each evening. Precautions should be taken against damage by storms at night during construction.

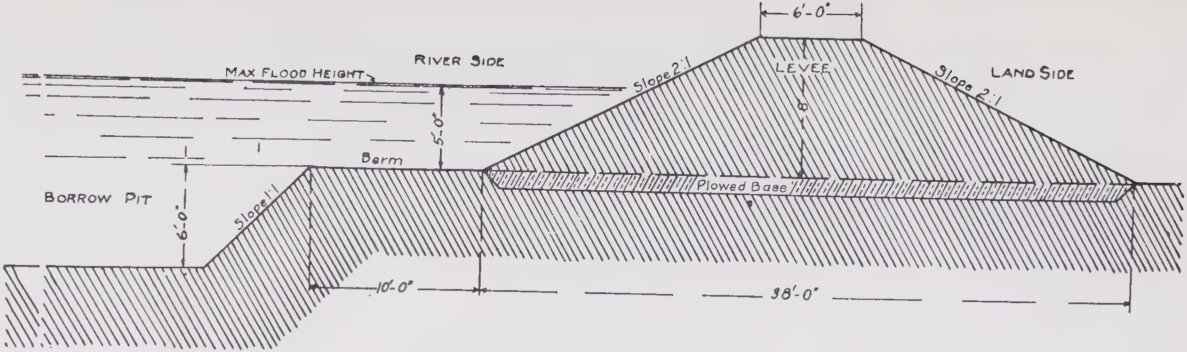
Filling the Trench. After inspection, tile are blinded by a workman who stands beside the trench and shaves mellow dirt from the sides of the ditch with a spade. A layer of mellow dirt three or four inches deep prevents the tile getting out of line. Plowing off the shoulders of the trench with a plow that is equipped with long eveners, will put the surface soil in the lower part of the trench. Other tools used for filling trenches are light road drags, or light road graders (Fig 24). Filling is more readily done before the dirt has become compact and settled.

Tiling contracts have been frequently let in the Willamette Valley at 30 to 60 cents a rod. The contractor usually furnishes the tools and the landowner furnishes the tile along the proposed drain. Whether board is to be provided and whether the trench is to be completely filled should be stated in the agreement. The contractor is usually required to begin at the outlet, lay true to grade, and pursue the work with due diligence. Arrangements are frequently made for securing pay for a part of the finished work during construction.

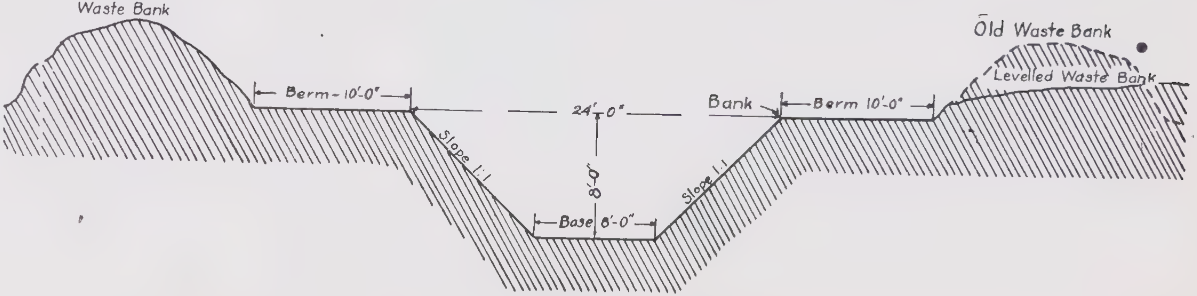
Outlets. It is of primary importance that the drainage system have a good outlet. Where the outlet is submerged, the velocity of the outflow is checked and sediment is apt to collect and clog the drains. The water should have a free spillway at the outlet. A partly submerged outlet can be kept clear where there is considerable volume of water and velocity of flow if a barrel or box is provided for collecting sediment and is cleaned out perhaps twice a year. The submerged outlet, however, is not desirable, as the land will never drain below the level of the water in the outlet.

The outlet pipe or tile may be vitrified or a corrugated culvert may be used. Such material is not affected by freezing or tramping of animals. To prevent rodents entering the tile, the end of the outlet should be screened, as in Fig. 26, with quarter-inch iron rods placed perhaps an inch apart. Where the outlet is submerged at times, an automatic flap gate may be provided which will be hinged at the top so as to close during times of high water or when the drainage ceases in the summer. A small bull-head should be provided at the outlet to force the water to run out through the tile instead of cutting out around it. This will also retain the earth bank and serve as a monument to mark the location of the outlet. The footing should extend out below the tile to form an apron on which the tile may discharge without causing erosion.

Silt Basins. Silt basins are small cisterns or manholes in the drains extending to the surface from a foot or more below the tile grade. These are usually provided in fence corners where two or more lines of tile join, or where the grade of the tile is decreased. Silt basins afford a means of collecting and cleaning out silt; they help to collect surface flood water quickly, prevent the drain from becoming clogged and may sometimes be arranged to afford watering places for the stock. Silt basins also permit inspection of tile and may increase the head of water on the outlet drain in time of high water. A small silt basin can be constructed by placing a twelve-inch sewer tile, having the required outlets,



Typical Cross Section for 8-ft. Levee



Typical Cross Section for Open Ditch

Fig. 27. Cross-section of outlet ditch and of levee.

on end. For larger silt basins, brick or concrete may be used. See Figs. 22 and 33.

At the Experiment Station it has been found convenient to construct silt basins or manholes of concrete (see Fig. 22). For the outer form the soil is used, and the inner form is made of staves like a silo, one of the staves being beveled so it can be removed after the concrete has set. The form makes the manhole five feet deep and three feet in diameter with a twenty-inch opening in the top, which may be covered with a concrete lid. The walls are about four inches thick. The tile lines are in place when the silt basin is constructed and the form sets tightly against the tile emptying into the silt basin. A surface inlet to the silt basin may be provided. The water should be screened and brought in on a grade to prevent roiling the sediment with the water in the silt basin. A few cubic feet of gravel or broken tile in the trench will make a fair inlet at the head of the drain.

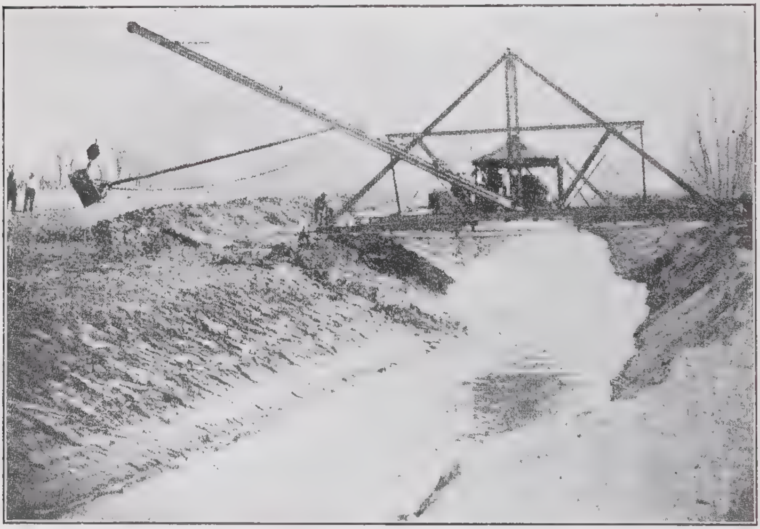


Fig. 28. Dry-land dipper dredger.

Junctions. The laterals may be constructed perpendicular to a main drain, excepting laterals which will discharge a large amount of water. Laterals which drain 3 acres or are 1000 feet long or over should join a main with a curve of five-foot radius so that the connecting tile will make an angle as small as 45°. The center of the lateral opening into the main should not be below the center of the main so as to prevent, as much as possible, the water from a main backing into the laterals.

Obstructions. The principal obstructions to tile are small animals, roots, and silt. Protecting all exposed ends of the tile system with screen or broken pieces of tile will prevent small animals entering. Roots of trees, such as willows, elm, tamarack, and soft maple, are troublesome. Cultivated plants, such as alfalfa, grape vines, and kale also give trouble where spring water runs in a tile line throughout the growing season. Water-loving trees within twenty or twenty-five feet of the drain should be girdled or cut down, or the tile can be cemented at the joints where the drains pass within this distance of the trees. Silt will be less troublesome in large tile. Small tile must be laid true to grade to prevent trouble, and if the lower inside lines of the tile are flush the carrying capacity will be greater and friction will be less.

To locate obstructions, dig holes in several places over the tile. A tile map and an end-gate rod will be of value in looking up and probing for tile lines. Below the obstruction the water will not rise in a dug hole but will fall away into the tile. Above the obstruction the water will rise and stand in the hole. The tile can be uncovered above and below the obstruction and can be cleaned out with a jointed sewer rod or by use of a long, limber pole or wire cable that is frayed out into a wire brush at the end.

A tile line to be permanently successful must be given some attention. Inspection and cleaning out of outlets and silt basins should take place at least twice a year—in the fall before the rains begin and again during the highest water of the season.

VII. DRAINAGE COSTS AND PROFITS

The cost of drainage varies greatly with the kind of soil, size of tile, thoroughness of drainage, method of construction and labor conditions. First of all, the number and size of the tile required must be determined before a definite estimate of cost can be made.

TABLE VI. APPROXIMATE PRICES AND WEIGHTS OF TILE

Size In.	Price per 1000 feet	Weight per foot	Average car-load	No. of ft. per ton
	Mar. 30, '21	lbs.	ft.	ft.
3.........	$39.00	4½	7500	400
4.........	$50.00	6½	6500	334
5.........	$65.00	9	5000	250
6.........	$104.00	11½	4000	182
8........	$178.00	18	2400	111
10........	$260.00	25	1600	80
12........		33	1000	60
14........		43	800	56

It may be necessary to make an allowance for freight in addition to the prices indicated in Table VI. Thirty thousand pounds is a minimum weight for a car-load of tile, and the average weight is about forty thousand pounds. As tile are rather bulky, a ton makes a fair wagon load. About five hundred four-inch tile or about two hundred six-inch tile can be hauled at one load. Two men with wagons when hauling to the same field can assist each other in loading and unloading.

Trenching. Digging the trench, laying the tile, and blinding in with three or four inches of mellow dirt commonly costs, in the Willamette Valley, from forty cents to a dollar a rod. The latter price frequently includes filling the trench. Reports (1914) on tile drains aggregating one hundred miles of tile that had been placed in the Willamette Valley showed that the average cost of digging and laying for each rod was thirty cents. The cost of digging and laying varies greatly with the kind of soil, size, and depth of tile and difficulties encountered, as shown in Table VII.

TABLE VII. APPROXIMATE COST PER ROD OF DIGGING TRENCH, LAYING TILE, AND BLINDING

Size of tile in inches	Depth in feet			
	3	4	5	6
4	$0.60	$1.00	$1.60	$2.40
5	0.70	1.10	1.70	2.60
6	0.80	1.20	1.80	2.70
8	0.90	1.30	1.90	2.80
10	1.00	1.40	2.00	2.90
12	1.10	1.50	2.10	3.00

Filling the trench with a plow or road drag has been done locally for ten to twenty cents for each hundred feet. Where the filling must be done by a more laborious process, it may cost twenty to twenty-five cents a hundred feet. To these items should be added 5 percent for surveys and superintendence, or 10 percent including outlets, silt basins, tools, and miscellaneous expenses.

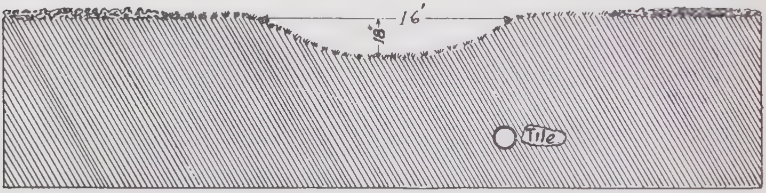


Fig. 29. Surface run.

The tile required for each acre, if laid in parallel lines and four rods apart, will be forty rods or, if six rods apart, thirty rods of tile will be required. At a total cost of one dollar a rod for laterals, this would mean forty dollars an acre for thorough drainage of the wettest areas on the farm. It rarely happens that more than 25 percent of the wet farms will require such thorough drainage. More frequently, wet swales or springy spots are drained with a random system of tile lines, making it possible to work the whole field at one time as well as increasing the production of the low area. In order to direct attention more fully to the cost and profit connected with drainage, a few typical examples of actual costs and results from different sections of the State are here given.

Results from Tile Drainage in Oregon. A drainage system was installed on a 72-acre field of **white land** one mile south of Albany by the United States Government in 1908. From three- to ten-inch clay tile were used, and the depth varied from three to four and one-half feet; the distance apart was purposely varied from sixty to one hundred fifty feet. Grades ranged from .2 to .5 foot for each hundred, and the entire cost of draining the seventy-two acres of land was $1,929.60, or $26.80 per acre. Drainage has made it possible to raise clover on this land, and the amount of underdrainage is gradually increasing each year. The system is declared a success by the owner of the tract, who estimates that the land is actually worth now for farming purposes four times what it cost previous to being drained.

Nearly twenty-five years ago, a drain system was installed in a white land area on the College farm at Corvallis under the direction of Professor French. The professor states that before being drained this area was so wet that it produced little but wild oats, tar weed, sorrel, and cat tails. Since it was drained, yields have steadily increased; last season, about five tons to the acre of clover hay was produced. The drains have paid for themselves over and over and are more effective today than ever.

Project No. 40 is installed near Troutdale. The field contained seven acres of peaty loam too wet to farm and producing only a marshy growth, providing a little pasture. The drain system installed included:

Tile, 5000 feet, 3-inch, 4-inch and 5-inch, costing	$129.00
Freight bill	12.00
Hauling of twelve loads at $2 a load	24.00
Digging 306 rods at 30 cents a rod	91.80
Total	$244.80

This cost is $34.97 an acre.

The owner states that until drained the field was not worked on account of wet places. The drain system was installed in 1912 and the following winter the main ran full for several days at a time. The following year, according to the owner, the piece produced $176 worth of potatoes to the acre. In 1914, this same field threshed out sixty-four bushels of oats to the acre. A stand of clover has been secured which was impossible before draining. The owner says, "We have received full returns already for our investment."

Project No. 43, an alkali area, is located in Crooked River Valley three miles east of Prineville. Before this land was drained, it was regarded as practically worthless because of the presence of alkali in the soil. Four acres of black loam were drained with the following costs:

Tile, 1500 feet	$35.00
Freight from Portland to Redmond	72.00
Hauling tile to ranch	7.50
Labor seven days at $2	14.00
Total,	$138.50

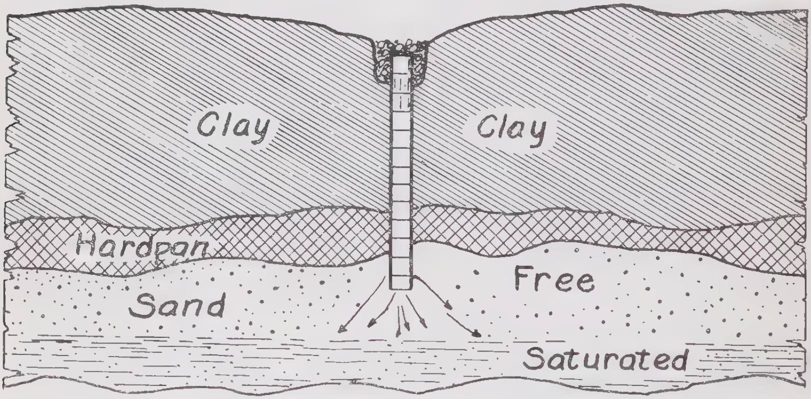
This cost is $34.63 an acre.

These figures are given by the owner who states:

"The tile were laid 60 feet apart and 3 feet deep and easily drained at that distance. If placed 4 feet deep and 100 feet apart the tile would have drained six acres instead of four. We were unable to get the latter depth owing to difficulty in securing an outlet for that level. Securing the tile in car-load lots would have reduced the expense to $89 or $22.25 an acre.

"Before the land was drained the crop in 1914 for the four acres was twenty bushels of barley or five bushels an acre. The crop in 1915 for the four acres was 278 bushels of wheat and barley or 69½ bushels an acre. Placing a value of eighty cents a bushel on this crop the result is $222.50, which, less the cost of draining, $138.50, equals $83.90 net gain this year from the above operation. From these results, we firmly believe that tile drainage is an unqualified success. This four-acre tract we tiled only as an experiment, and we intend to drain forty acres more as quickly as possible. There are few investments which pay so well."

Profits from Drainage in Oregon. Timely drainage usually pays in increased crops and increased land value. Those who have drained say that it pays. The writers have examined the greater part of the tile systems in use in the Willamette Valley and other parts of Oregon and, while a few drains in use are too small or poor depth, or have been poorly constructed, we fail to find a tile system properly installed in the Willamette Valley which has not been successful. Tile drains usually improve in effectiveness for years. If properly installed, they should add value to the land equal to their cost. The profits from drainage are large, drains frequently paying for themselves within a few years. It therefore costs money to hold wet land. Most of our wet lands, particularly in the Willamette Valley, will pay a better rate of interest on the total investment if drained. Drainage is a permanent improvement; it is the fundamental step in the improvement of our wet lands; it makes rotation with soil-building crops possible and constructive soil treatment effective.



Vertical drain conducts surface water through impervious soils to porous strata below.

Fig. 30. Vertical drain.

VIII. FARM OPERATIONS THAT AID DRAINAGE RECLAMATION

Experiments with Drained Land. The plan of drainage plots (Fig. 8) shows the general plan for studying the effect of different soil treatments for improving the drainage qualities of the land included in the drainage experimental tract on the Station farm. It is planned to seed the whole field to one crop each year and to employ a three-year rotation; namely, spring barley, followed by clover, one crop a year, then a cultivated crop, such as corn. The value of lime, manure, green manure, and combinations of these treatments, is to be tried out on duplicate plots and check plots.

In the new experiment field, the value of straw as compared to gravel, cost and effectiveness considered, in helping the water to enter the tile, and the effects of each, will be measured and judged by the comparative yield and the relative amount of run-off.

Operations that Aid Water in Entering Tile. The following things can be done to aid the tile in collecting water in retentive soils. (1) In draining a saucer-like area, lay out the protecting drains so as to collect seepage water or surface water before it gets onto the retentive soil. (2) Use surface inlets in the upper side of the field or at points where the surface water is apt to run onto the heavier soils; also in the lower points in the field, if necessary, to permit water to pass down into the drains. (3) After laying and binding the tile, allow the trench to remain open a few weeks, if possible, so air can come in contact with the subsoil and cause it to slack and crumble. (4) In filling the trench, put in sod or straw and then the top soil immediately over the tile. Straw will decay, thereby increasing the open space, whereas gravel may silt up. Where the grade is steep, however, gravel would protect tile from washing out better than straw. Put the sticky, sub-surface soil, if it is used, in the top of the trench. (5) Plow the land deeply when it is dry enough to crumble. (6) After draining, lime will become more effective and will aid in mellowing the soil. (7) Drainage and liming will, in most cases, make it possible to raise clover on the land. Clover roots will penetrate the drained soil and will be of great value in loosening up our valley land so that water can pass through and get into the drains. (8) Where possible, plow the land so that the dead furrows will fall directly over and parallel to the laterals, giving the surface a slight slope toward the laterals. Surface water that collects in these dead furrows will pass into the laterals more readily. If it remains on the surface temporarily, catch basins can be provided that will aid it in passing into the drains underneath.

Treatment for White Land. Clover should be grown on heavy land like our white land about every third year in rotation with grain and cultivated crops or similar crops. A decidedly large relative outflow has been observed in the wet season following a clover crop, and on such fields water has stood to a lesser extent. With manure and clover plowed under once in each rotation, the yields of these crops on our white land can be built up to compare very favorably with the naturally drained brown loam soil in this valley.

Treatment for Peat Land. Peat marshes can be burned off to dispose of the rank vegetation when there is moisture enough to protect the soil from burning out. The use of a rush cutter, as shown in Fig. 23, will facilitate disposing of rushes on low land. This native growth can be largely replaced by cultivated grasses and clovers to supply pasture and forage until the native vegetation is subdued. The cultivated crops may depend on altitude, but rank-growing crops which are hardy and and resistant to excessive moisture, such as rye, oats, field peas, or barley, can be used while the sod of the newly broken marsh is decaying. Open ditches for laterals will frequently be used during this process (see Fig. 26), and as the marsh settles more permanent drains will be put in, which can be extended as needed to perfect the drainage, so that more intensive cultivated truck crops can be grown.

Treatment for Alkali Lands. Alkali land, after being drained, can be somewhat improved, where water is available, by flushing off accumulated surface salts by late fall irrigation. Shallow open ditches may help remove heavy alkali crusts. In two or three seasons, careful handling will usually remove the alkali sufficiently so that by deep plowing hardy crops such as rye or sweet clover can be established. It may take from one to three years to complete the reclamation of these lands, depending upon the amount of alkali and the retentiveness of the soil. Such crops as rye or sweet clover plowed under will supply humus and nitrogen and loosen up the soil so that moisture conditions may be more readily controlled. During the process they may provide some return in the form of pasturage. The alkali lands when thoroughly reclaimed are usually strong in the necessary plant foods and suitable for alfalfa and the other staple crops of the region.

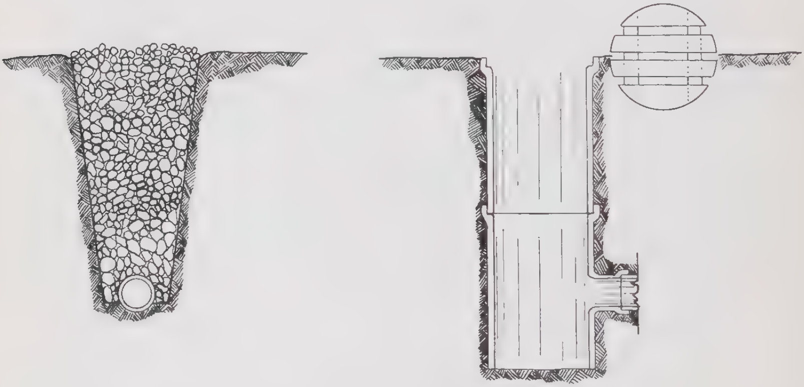


Fig. 31. Inlets.

The treatments above described are calculated to assist in loosening up and aerating the drained soils and to assist water in entering the drains provided. Legumes and manuring crops suggested will also supply humus and nitrogen. which are ingredients none too plentiful in much of the white land and irrigated and alkali land. This treatment would pave the way for cash crops, make it possible to get the highest possible efficiency out of the drains installed, and render the enterprise thoroughly successful and profitable.

The Open Ditch for Drainage. The primary object of open ditches is to afford an outlet for tile drains. The ditch should be deep enough for the tile outlets; i. e., six to eight feet below the general level. The width should be sufficient to afford the required capacity based on the slope, area, and run-off coefficient. In no case except in raw peat should side slopes be steeper than one to one, and in sandy soils it may be necessary to use a slope of one to two. The waste bank must be thrown well back and perhaps leveled. The dredge is used in outlet ditch construction. Such a ditch is shown in Fig. 28.

It is difficult to provide such ditches except where several landowners are interested and will organize a drainage district. The district law provides that each parcel of land shall pay in proportion to the benefits received. It is a businesslike way of accomplishing the drainage of large areas of flat land or where tile outlets are not available.

Large Tile. The present tendency is to use large tile instead of the small open ditch. A broad, sodded surface run for surface run-off used in combination with a tile for under drainage is often good practice. Tile drains as large as twenty-four inches are used. The extra cost of tile is more than offset by the use of the land over the tile, which is the best-drained part of the field, and by the saving of cost of maintenance of open ditches. The open ditch costs slightly less at first, but this is more than offset by the following disadvantages:

(1) It occupies valuable land which if tiled woul be tillable.

(2). Divides fields, making parts inaccessible.

(3). Harbors weeds, plant diseases, and mosquitoes.

(4). A small open ditch is difficult to maintain.

(5). Requires bridging and fencing in many cases.

(6). Unsightly.

If open ditches are used, some of the disadvantages may be offset by observing the following principles:

(1). Follow property lines wherever possible.

(2). Construct the ditch of ample size and to a regular grade such that it will be self-cleaning as far as possible.

(3). Follow straight courses or regular curves, so as to avoid trouble from erosion and silting.

(4). Consult a good engineer if the ditch is of any size or length.

DISCHARGE OF WILLAMETTE VALLEY STREAMS

By

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The Water Resources Branch of the United States Geological Survey in November, 1920, established four gaging stations on streams in the Willamette Valley, the discharges of which are of interest in connection with drainage enterprises.

Oak Creek has a drainage basin lying almost wholly within the confines of the valley floor, and its discharge can be used in studies of drain capacities. The Calapooia River basin is about equally divided between valley and foothills. Long Tom River and Muddy Creek draw a larger portion of their flow from area outside of the valley floor, but both streams have in places a rather flat and tortuous channel which must eventually be improved to provide adequate capacities to keep flood waters off their bordering lands. Data in regard to the run-off of each of these streams are presented below. More complete data can be furnished by the Portland office of the Water Resources Branch of the United States Geological Survey.

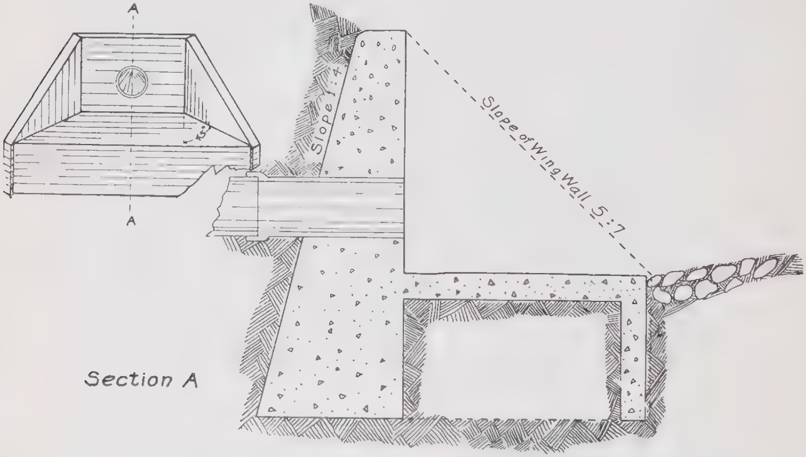


Fig. 32. Outlet.

LONG TOM RIVER NEAR MONROE, OREGON

Location. At highway bridge in Sec. 21, T. 14 S., R. 5 W., 1½ miles north of Monroe, below all tributaries.

Drainage Area. 400 square miles, mostly valley and eastern foothills of Coast Range.

Channel Capacity. 2,200 second-feet at 7-foot stage above which overflow occurs. Increase about 500 second-feet per foot rise at 7 feet; 1,500 second-feet per foot rise at 10 feet.

Maximum Discharge. Highest stage during winter of 1920-21 was 11.1 feet on December 12, determined from high-water marks, discharge, 6,900 second-feet, or 17.2 second-feet per square mile. Floods of January 1 and 6 reached a stage of 10.3 feet, discharge 5,320 second-feet.

Flood Profile. The following profile of the extreme high water along the lower portion of the river was obtained by leveling to high-water mark.

PROFILE OF 1920-21 HIGH WATER ON LONG TOM RIVER

Location	Distance from mouth	Elevation of highwater	Fall
	mi.	ft.	ft.
Highway bridge in Monroe	11.8	278.7	
Gage in sec. 21, T. 14, S., R. W.	9.9	270.5	1.9
S. E. ¼ sec. 16, T. 14 S., R. 5 W.	9.2	267.3	3.2
S. W. ¼ sec. 10, T. 14 S., R. 5 W.	8.1	265.4	1.9
Side channel, in S. E. ¼, Sec. 34, T. 13 S., R. 5 W.	5.5	258.0	7.4

Total fall 20.7 feet in 6.3 miles or 3.04 feet per mile. River channel cannot be materially shortened.

MONTHLY DISCHARGE OF LONG TOM RIVER NEAR MONROE, OREGON. PERIOD ENDING MARCH 31, 1921.
(Drainage area 400 square miles)

	Discharge in second-feet				Run-off	
Month	Max.	Min.	Mean	Per sq. mi.	Depth on drainage area	Total
					in.	acre ft.
Nov. 13-30	5,160	168	2,720	6.80	4.55	97,100
Dec.	6,500	1,480	2,840	7.10	8.19	175,000
Jan.	5,320	1,070	2,880	7.20	8.30	177,000
Feb.	3,960	1,190	2,470	6.18	6.44	137,000
March	2,550	500	1,070	2.68	3.09	65,800
The period					30.57	652,000

MUDDY CREEK NEAR CORVALLIS, OREGON

Location. At highway bridge in Sec. 29, T. 12 S., R. 5 W., 3 miles south of Corvallis.

Drainage Area. 120 square miles; mostly foothill area.

Channel Capacity. 540 second-feet at stage of 10 feet. Increase about 80 second-feet per foot of rise at 10 feet, 400 second-feet per foot of rise at 15 feet.

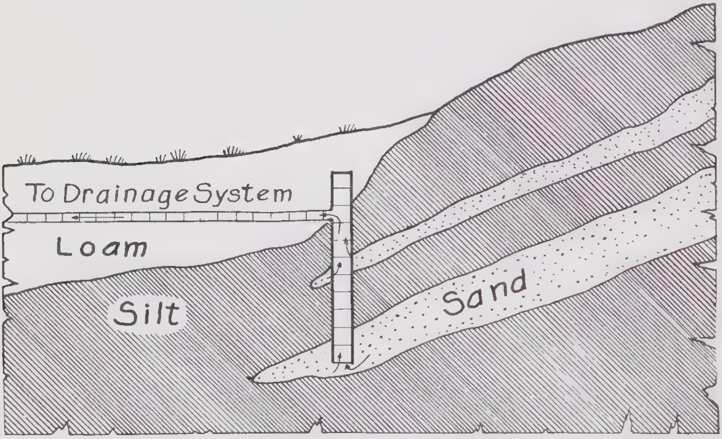
Maximum Discharge. Highest stage recorded during winter of 1920-21 was 15.5 feet on November 19 and December 12, discharge 1,700 second-feet, or 14.2 second-feet per square mile. Flood of January 5 reached a stage of 15.4 feet, or 1,660 second-feet.

Flood Profile. The following profile of the extreme high water along the lower portion of the river was obtained by leveling to high-water marks.

PROFILE OF 1920-21 HIGH WATER ON MUDDY CREEK

Location	Distance from mouth: Present channel	Distance from mouth: Rectified channel	Elevation high water	Fall
	mi.	mi.	ft.	ft.
Near Bruce station, on Tp. line between T's 13 and 14, S.	20.6	12.7	258.1	
Highbridge in sec. 8, T. 13, S., R. 5 W.	10.7	6.7	242.9	15.2
Gage at bridge in sec. 29, T. 12 S., R. 5 W.	3.7	3.0	234.7	8.2
Mouth	0	0	228.2	6.5

Total fall 29.9 feet in 20.6 miles or 1.45 feet per mile. Artificial channel, cutting out bends, would reduce distance to 12.7 miles, or 62 percent of original distance.



Relief Well: Pentrates pervious strata and permits the entrance of water into the drainage system that otherwise would penetrate the lower lying soil.

Fig. 33. Relief well.

MONTHLY DISCHARGE OF MUDDY CREEK NEAR CORVALLIS, OREGON
PERIOD ENDING MARCH 31, 1921.
(Drainage area 120 square miles)

Month	Discharge in second-feet: Max.	Min.	Mean	Per sq. mi.	Run-off: Depth on drainage area	Total
					in.	acre ft.
Nov.	1,700	15	423	3.52	3.93	25,200
Dec.	1,580	366	747	6.22	7.17	46,000
Jan.	1,620	342	777	6.48	7.47	47,800
Feb.	1.060	348	700	5.83	6.07	38,900
Mar.	1,270	130	404	3.37	3.88	24,800
The period					28.52	183,000

CALAPOOYA RIVER NEAR TANGENT, OREGON

Location of Gage. At highway bridge in sec. 32, T. 12 S., R. 3 W., 4 miles southeast of Tangent, Linn county, 1 mile southeast of bridge on Pacific Highway.

Drainage Area. 262 square miles, about equally divided between flat valley lands and the foothills of the Cascade Range.

Channel Capacity. 2,000 second-feet at 12-foot stage, increase below this about 200 second-feet for each foot rise in stage; above 12-foot stage capacity increases rapidly, reaching 5,300 second-feet at 18-foot stage, with increase of 1,000 second-feet between 17 and 18 feet.

Maximum Discharge. Highest stage recorded during winter of 1920-21 was 17.4 feet at 8 a. m., December 31, discharge 4,700 second-feet or 17.9 second-feet per square mile. Flood of December 11 reached a stage of 17.0 feet, discharge 4,300 second-feet, that of January 5, 17.2 feet, discharge 4,500 second-feet.

Flood Profiles. The following profile for the extreme high water of 1920-21, was obtained by leveling to high-water marks.

PROFILE OF 1920-21 HIGH WATER ON CALAPOOYA RIVER

Location	Distance from mouth		Elevation at high water	Fall
	Present channel	Rectified channel		
	mi.	mi.	ft.	ft.
⅛ mile north of Tp. line, S. E. ¼ sec. 32, T. 12 S., R. 3 W.	25.0	15.1	252.5	
Gage, in sec. 32, T. 12 S., R. 3 E.	24.2	14.3	252.2	.3
Railway bridge in Sec. 30 T. 12 S., S., R. 3 W.	21.7	12.2	243.7	8.5
Highway bridge 2 mi. west of Tangent, N. W. ¼ sec. 14, T. 12 S., R. 4 W.	14.0	9.1	229.9	13.8
Highway bridge one-half mile S. E. of Gray, S. W. ¼ sec. 35, T. 11 S., R 4 W.	10.8	6.8	220.8	9.1
1 mi. S. E. of Pirtle N. W. ¼ sec. 26, T. 11 S., R. 4 W.	6.3	5.0	210.8	10.0
Bridge on Albany-Corvallis road, N. W. ¼, sec. 13, T. 11 S., R. 4 W.	2.3	2.2	197.1	13.7

Total fall 55.4 feet in 22.7 miles by present channel, or 2.44 feet per mile. Artificial channel, cutting off bends would reduce distance to 12.9 miles or 57 percent of original distance.

MONTHLY DISCHARGE OF CALAPOOYA RIVER NEAR TANGENT, OREGON
PERIOD ENDING MARCH 31, 1921.
(Drainage area 262 square miles)

Month	Discharge in second-feet				Run-off	Total
	Max.	Min.	Mean	Per sq. mi.	Depth on drainage area	
					in.	acre ft.
Nov. 27-30	2,980	1,310	2,170	8.29	1.23	172,000
Dec.	4,570	808	1,980	7.56	8.72	122,000
Jan.	4,390	------	1,900	7.25	8.36	117,000
Feb.	3,840	856	2,010	7.67	7.99	112,000
March	2,710	352	991	3.78	4.36	60,900
The period					30.66	429,000

OAK CREEK NEAR ALBANY, OREGON

Location. At highway bridge, one mile south of Fry station on Lebanon branch of Southern Pacific Railroad, 5 miles southeast of Albany, and same distance above mouth, in N. W. ¼ sec. 34, T. 11 S., R. 3 W.

Drainage Area. 39 square miles; at least 80 percent of which lies within the valley floor.

Channel Capacity. 660 second-feet at 5-foot stage, increasing 240 per foot rise, two channels at gage, but no considerable overflow.

Maximum Discharge. Highest stage recorded during winter, 5.7 feet Nov. 19, discharge 835 second-feet or 21.4 second-feet per square mile.

Precipitation. This stream affords a rough comparison between precipitation on Willamette Valley areas and the run-off which it causes. The station at Albany gives a close approximation of the rainfall over the valley portion of the basin. The foothill portion will receive an amount possibly 25 percent greater; which would make the average for the basin 5 to 10 percent greater than at Albany. On this basis the run-off from Nov. to March inclusive, was about 63 percent of rainfall.

MONTHLY DISCHARGE OF OAK CREEK NEAR ALBANY, OREGON
FOR PERIOD ENDING MARCH 31, 1921.
(Drainage area 39 square miles)

Month	Discharge in second-feet				Run-off		Precipitation at Albany
	Max.	Min.	Mean	Per sq. mi.	Depth on drainage area	Total	
					in.	acre ft.	
Nov.	760	4	78.1	2.00	2.23	4,650	5.53
Dec.	660	70	222	5.69	6.56	13,600	7.75
Jan.	685	45	178	4.56	5.26	10,900	6.72
Feb.	496	32	174	4.46	4.64	9,660	6.59
March	440	11	83.4	2.14	2.47	5,130	4.82
The period					21.16	43,900	31.41

INCHES RAINFALL AND AVERAGE MONTHLY PERCOLATION BY SOIL TYPE
OREGON AGRICULTURAL COLLEGE EXPERIMENT STATION, DEPARTMENT OF SOILS.
Lysimeters 3⅓'x3⅓'x4' deep

Month	Rainfall	Percolation	
		Brown silt loam	Silty clay loam
	in.	in.	in.
Nov.	4.90	2.31	2.33
Dec.	7.97	6.39	7.49
Jan.	7.15	7.19	6.84
Feb.	5.38	5.82	4.99
Mar.	4.23	3.10	3.13
Total	29.63	24.81	24.78
Percent Run-off		83.80	83.5

The following observations have been noted:

(1). Willamette has a total water-holding capacity of 15 to 20 percent greater than Dayton.

(3). Dayton will discharge at a rate 15 to 20 percent greater than the Willamette at the time of the maximum run-off.

(4). Willamette will discharge more steadily and continue an appreciable discharge for a longer time than the Dayton. The Dayton is more spasmodic than the Willamette.

There is reason to believe that these conclusions obtain under field conditions to the extent shown by the experimental data.

OUTFLOW DATA, EXPERIMENTAL TILE DRAINS, OREGON AGRICULTURAL COLLEGE EXPERIMENT STATION, CORVALLIS

Date	Acre inches per acre per 24 hrs.		
	130 Ac. Tr.	10 Ac. Tr.	Rainfall for period
1920			
Nov. 30	.072	.076	
Dec. 7	.029	.160	
11	.655	.460	
14	.176	.140	
21	.082	.170	
28	.036	.318	
1921			
Jan. 4	.152	.223	
11	.055	.166	
18	.227	.305	
21	.069	.112	
29	.306	.318	
Feb. 8	.194	.230	
20	①	②1.910	
26	.055	.160	
Mar. 4	.035	.033	
16	①	②1.530	
23	.100	.191	
30	.024	.160	

① Wier flooded. ② Estimated.

Station Bulletin 179 May, 1921

Oregon Agricultural College
Experiment Station

Poultry Housing

By

JAMES DRYDEN

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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Poultry Housing

By

JAMES DRYDEN

The problem of good housing of fowls is closely related to the maintenance of health and vigor in the flock. In the past twenty years ideas have changed considerably in regard to poultry-house construction. Formerly, as now, the main consideration was comfort and health of the fowls, but comfort is now secured by building houses on a different plan from those of twenty years ago or more. The change has been one of the two or three important factors responsible for the development of a profitable poultry husbandry.

In the old plan of housing, the comfort of the fowls was obtained or sought by building warm houses, so-called, which included double-boarded walls and sufficient glass windows to let in a little light and sunshine. They were usually closed up tight in the winter time, and the result was damp, cold houses. The sun during the day, striking through the windows, caused the temperature to run up. The same glass windows were responsible for a severe drop in temperature during the night. Not the high or low temperature, but the wide range of temperature between day and night was responsible for the failure of this kind of house. With a high temperature during the day, the air took up much moisture, and at night the temperature dropped so much that the moisture in the air was condensed on the walls and in cold sections froze, making the house far from comfortable. This kind of house offered a favorable environment for various poultry diseases, and the diseases did not miss the opportunity.

This type of house, however, has now been scrapped, and the comfort and health of the fowls is secured by building, not the so-called warm houses, but rather cold houses that maintain a better equilibrium between night and day temperatures. Glass windows are largely discarded, and the double wall and dead air space idea is now pretty well a relic of the past. The modern idea is an open-front house, and it is this type of house that has brought success to poultry keepers. The satisfactory result has come chiefly through attention to ventilation.

LOCATION

(1) **Soils.** Chickens will thrive on a great variety of soils, but certain kinds are more adapted than others to successful poultry keeping. Especially in choosing a location for commercial poultry farming, heavy clay soils should be avoided, if possible, as they are hard to keep clean and sanitary. A rather light porous soil is preferable; this is drier in wet weather and not as hard in dry weather. A wet soil is colder than a dry one.

(2) **Drainage.** If the ground selected has not good natural drainage, provision should be made either by under drainage or by open

ditches for carrying off the surplus water. The water should not be allowed to stand in the yards. Muddy feet mean muddy eggs. Dampness means catarrh, roup, rheumatism, tuberculosis, etc.

(3) **Air Drainage.** Air drainage is sometimes as important as soil drainage. Cold moist air seeks the lower levels. It is better to locate the house and yards on higher levels where there is some air movement to carry off the cold, damp air or prevent its becoming stagnant. Fowls should not, however, be exposed to high winds. You will notice that on windy days the fowls mope around in sheltered corners or in houses. This is not favorable to high egg production. Sufficient air drainage without interfering with the comfort or activity of the hen is the ideal condition. The houses may be built on the leeward side of an orchard or in the shelter of buildings. A windbreak of trees may be set out to provide shelter.

(4) **Sunshine.** If possible the houses and yards should be built where they will get full benefit of the sunshine. Face them south unless the prevailing winds are from that direction. Sunshine is a germ destroyer and a better egg producer than red pepper or other condimental foods.

(5) **Other Points.** Other points that should be considered in locating the houses are: (a) The convenience of the attendant. Nearness to the feed and water supply will save labor. (b) Building the houses away from the other buildings. This will make it easier to keep the premises free from insect pests, rats, etc. (c) A location near a city market or a good shipping point, other things being equal, should be given the preference.

REQUIREMENTS

No one style of poultry house will suit all conditions; besides, fowls may be kept successfully in different kinds of houses. There are certain principles, however, that should govern in the building of any kind of poultry house.

(1) **Ventilation.** Fowls require considerably more fresh air than other farm animals. It has been estimated that a hen in proportion to her weight requires double the weight of oxygen that a man or a horse requires. The amount of air breathed per 1000 pounds live weight of hens is given by King as 8,272 cubic feet in 24 hours, the requirement of a man being 2,833 and a cow 2,804 cubic feet. Ventilation, moreover, keeps the house dry. A close, warmly built house, with glass windows, is always damp, because of the extremes of temperature between day and night. Dampness is overcome by ventilation. Ventilation can best be furnished by leaving one end or one side open or partly open. In cold sections or exposed or windy locations this opening may be covered with a curtain of muslin; this will admit air, yet add to the comfort of the fowls. In most sections, however, the curtain will not be needed. The other three sides of the house should be draft-proof. The idea is to give plenty of ventilation without drafts.

(2) **Protection from Cold and Storms.** A good poultry house should afford protection from the winds and the storms and severe

weather. A little shelter from the winds and the storms will increase egg yields. A cold wave or a sudden change to colder weather means an immediate demand for increased fuel to keep up the heat of the body. In this case the fuel is the food that the hen eats, and the food that has been going into the making of eggs will be drawn upon for fuel purposes. Any shelter, therefore, that protects fowls from storms or sudden changes in temperature is an incentive to egg production. Fowls maintain rugged health roosting in trees, but the sudden and frequent changes in the weather to which they are subject in the trees interfere with egg production.

(3) **Space Required per Fowl.** The house, while affording protection from storms, should also furnish scratching room, for activity is the life of the hen. Where there is little or no snow or where the chickens can be out of doors almost every day in the year, about two square feet of floor space for each fowl will be sufficient. This will apply to flocks of twenty or more hens. For smaller flocks a more liberal allowance of space should be made. Where the climate is such that the fowls will seek shelter part of the year rather than go out of doors in the yards and fields, more floor space should be provided, say three to four square feet for each fowl. The house should be built high enough for a man to work in without bumping his head. This height will allow sufficient air space for the fowls.

(4) **Floors.** Floors are not always necessary in poultry houses. A floor will be an advantage where the ground is inclined to be damp, but where it is well drained and porous there need be no floor. A wooden floor gives protection for rats underneath, and for this reason a cement floor is preferable. On the other hand, cement floors do not permit moving the house, where this is desired. Where an earth floor is used it should be higher than the ground outside of the house, to prevent water running in. It is a good plan to fill the floor with six or eight inches of clean, coarse sand, and once a year or oftener to scrape off part of this and replace it with clean sand. This will keep the floor comparatively clean and lessen the danger from diseases in the flock.

THE PORTABLE HOUSE

The portable house is used where the colony system prevails. Much of the trouble from diseases comes from keeping the chickens on the same ground year after year. By keeping them on clean ground, which is possible with portable houses, they are under natural and hygienic

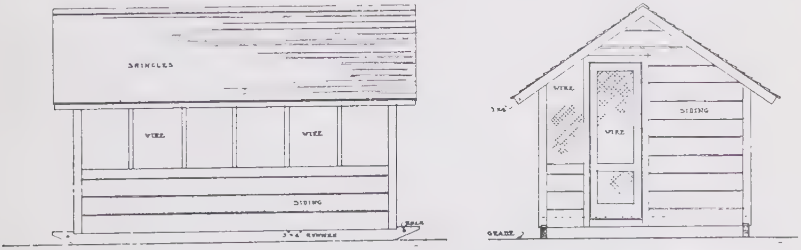


Fig. 1. Side and end elevation of O. A. C. portable colony house.

conditions. This system, moreover, fits in with a system of crop rotation on the farm. About fifty chickens to the acre will keep the land in high fertility. Besides, the chickens will find a considerable portion of their food in the waste grain and weed seeds, grasshoppers, and other insects. They often rid the farm of grasshoppers and other insects, thus saving valuable crops. Another important advantage of the colony system, is the fact that the fowls are more active when they have the liberty of fresh fields than when confined in yards. Finally, with the colony system

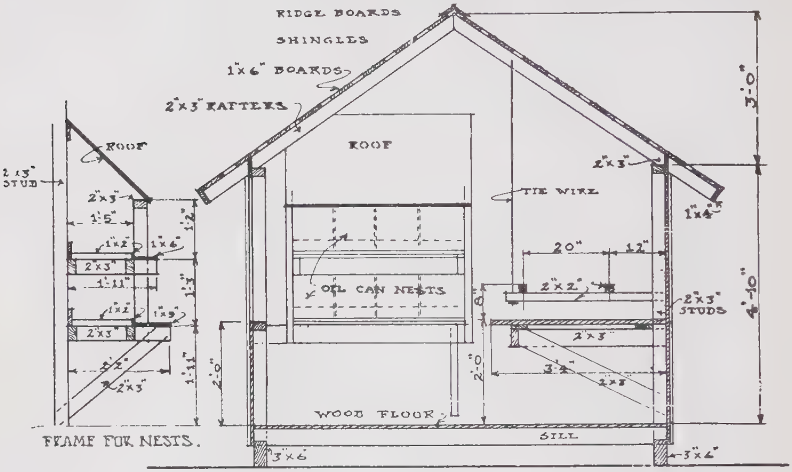


Fig. 2. Plan of frame for nests and end section of O. A. C. portable colony house.

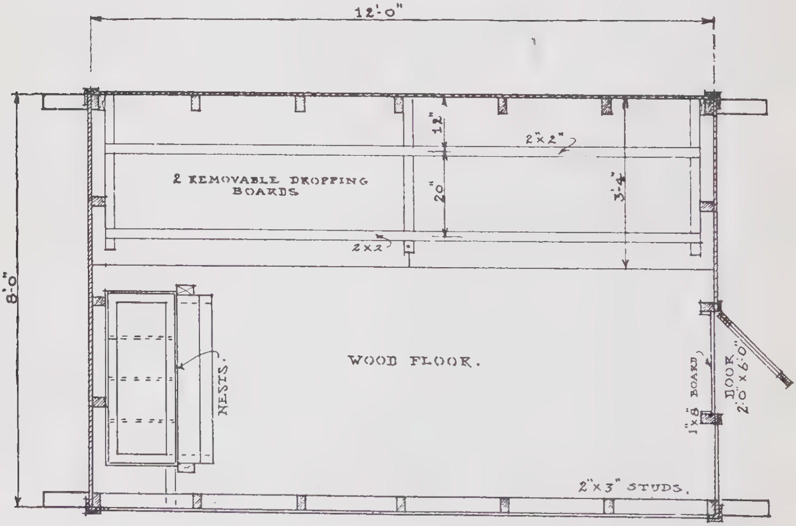


Fig. 3. Floor plan of O. A. C. portable colony house.

there is no expense for fencing. If fowls are kept on an extensive scale, where much cheap land is available, the colony system is undoubtedly the best, but with high priced land any system of fifty hens to the acre is out of the question.

A good size for a portable house is 8 by 12 feet, which will accommodate 40 fowls. A team of horses will pull a house of this size, which is built on runners. It may be used as a stationary house.

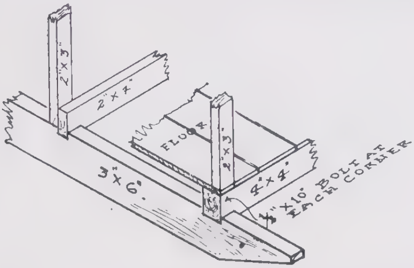


Fig. 4. Detail of runners for O. A. C. portable colony house.

DETAILS OF CONSTRUCTION

Bill of Materials for Portable Colony House 8′x12′

Lumber.

2	3″x6″	14 feet long runners.
2	4″x4″	8 feet long sills.
5	2″x4″	8 feet long sills.
14	2″x3″	5 feet long studs.
4	2″x3″	7 feet long studs.
2	2″x3″	8 feet long studs.
3	2″x3″	12 feet long plates.
14	2″x3″	6 feet long rafters.
8	2″x3″	12 feet long nest frames, etc.
2	2″x2″	12 feet long roosts.
3	2″x2″	3 feet long roost supports.
175	board feet	8″ lap for flooring and dropping boards.
125	board feet	6″ roosting boards and slats for dropping boards.
260	board feet	8″ channel rustic siding, No. 2.
1250	shingles.	
4	1″x4″	corner boards, each 6 feet long.
4	1″x3″	corner boards, each 6 feet long.
5	1″x3″	door and door opening. Each 12 feet long.
2	1″x4″	14 feet long cornice finish.
4	1″x4″	6 feet long cornice finish.
1	1″x3″	14 feet long ridge board.
1	1″x4″	14 feet long ridge board.
5	1″x3″	door and door opening. Each 12 feet long.
1	1″x2″	14 feet long stops for oil can nests.

Hardware.

6	lbs. 8 D case nails.
10	lbs. 8 D common.
3	lbs. 16 D common.
4	lbs. shingle nails.
1	pair of strap hinges.
6	feet of heavy wire.
18	feet of 3′ mesh wire for door and front.
8	10″ 1x10″ x 15″ oil cans for nests. 2/3 of one end cut out.
4	½″x10″ anchor bolts.

A 100-HEN HOUSE

A plan of a good house of 100-hen capacity is given herewith. A cement floor, on the whole, is the most satisfactory in a permanent house, but it may not be necessary in some locations.

BILL OF MATERIAL

Concrete work. (1:2.5:5 mixture. 1:2 wearing surface.)

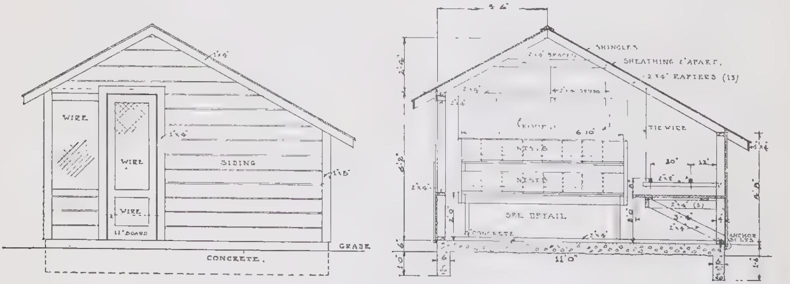
10 barrels of Portland cement.
2 cubic yards of sand.
5 cubic yards of gravel.

Lumber.

7 4″x4″ 6 feet long.
14 2″x4″ 10 feet long.
12 2″x4″ 12 feet long.
4 2″x2″ 12 feet long.
2 2″x2″ 14 feet long.
125 board feet of 8″ ship lap for dropping boards.
400 board feet of 8″ channel rustic siding.
3250 shingles.
50 1″x6″ 14 feet long for roof sheathing.
32 1″x4″ 14 feet long for miscellaneous.
4 1″x5″ 14 feet long for eccentric corner and ridge boards.
2 1″x2″ 10 feet long for stops for oil-can nests.

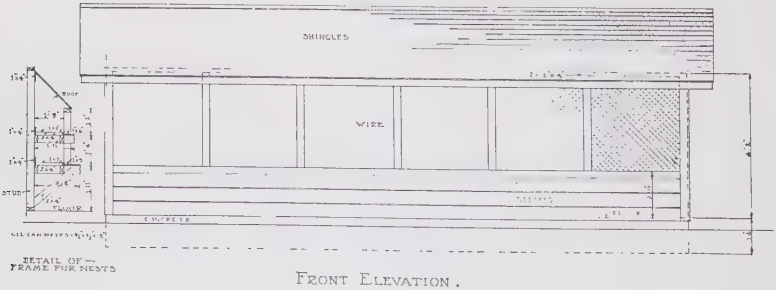
Hardware.

18 lbs. 8 D case nails.
18 lbs. 8 D common.
6 lbs. 16 D common.
10 lbs. shingle nails.
One pair of 4″ strap hinges.
Three heavy wires six feet long each.
30 feet of 4′-1″ mesh wire.
Six ½″x10″ anchor bolts for bottom plate.
16 10″x15″ oil cans for nests; 2/3 of one end cut out.
Paint.



End. Section.

Fig. 5. End view and section of 100-hen house.



Front Elevation.

Fig. 6. Front elevation and detail of frame for nests, 100-hen house.

INTERIOR ARRANGEMENT

Whether the house be a portable farm poultry house, a breeding house, or a large commercial laying house, practically the same arrangement of the interior may be had. All the floor space should be used by the fowls for scratching. If possible all nest boxes, perches, hoppers, etc., should be movable. This will make it easier to clean out the house and to keep it free from lice and mites.

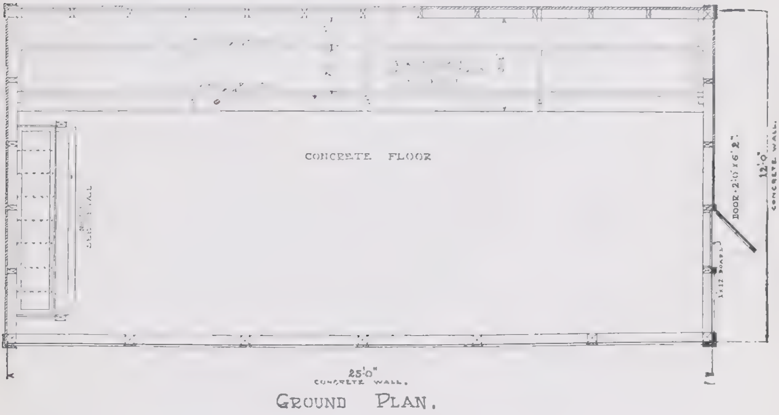


Fig. 7. Ground plan of stationary house.

The Nests. Nests for laying hens should be somewhat secluded, for fowls are less likely to acquire the egg-eating habit when the nests are in a darkened place. They should be from 10 by 12 to 12 by 14 inches in size and 8 to 10 inches high, the larger breeds requiring the larger size. A cheap and serviceable nest may be made out of a five-gallon oil-can by cutting the end out, leaving about three inches at the bottom to keep the nest material in the nest. Such a can may be easily cleaned either by washing or spraying. The illustration shows top of can taken off; this makes the nest more roomy. Several of these nests may be set on a platform about 2 feet from the floor, turning the entrance of the nest towards the wall and leaving a space or walk along the back. The nest platform should be about two feet from the ground, being nailed to a cleat on the side of the house and braced from top of sill. Over the nests, to keep the chickens from standing on them and to help to darken them, should be fitted a sloping top. This top should be built high enough so that the attendant can see into the nests. One nest to five or six hens should generally be provided. The plan of

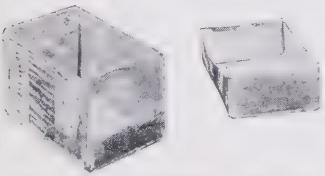


Fig. 8. Good serviceable nests may be made out of 5-gal. oil-cans. Such a nest is cheap and easily cleaned. An oil-can may also be used for watering the flock.

putting the nests under the platform, shown in the 500-hen house plan, will be satisfactory for the 100-hen house as well as the portable house. These nests are made in sections of five ten-inch nests and slide under the platform. The hen enters at the rear. It is recommended that the nests be made with wire bottoms mainly because there will be fewer eggs broken. As the hen rises when she lays, the egg is likely to break when it drops on the board bottom, since straw may not always cover the bottom of the nest. The front of the nest is hinged and it is readily opened in gathering the eggs.

Broody Coop. A coop for broody hens for the commercial house is placed over the platform on each side of partition in the center of the house. This coop should be about 2 by 3 feet running back to the wall, and made of slats 1½ inches apart, with a wire bottom of 1-inch poultry netting. This coop should not interfere with the raising or lowering of the perches.

Perches. It is important that they be placed far enough apart to prevent the fowls becoming overheated and to assure fresh air for them to breathe. The fresh air house must furnish fresh air at night as well as during the day. The perches are made of 2-by-3-inch stuff. The hens roost on the 2-inch surface, which should have the sharp edge planed off.

THE COMMERCIAL LAYING HOUSE

Commercial poultry farms, which in this State have been largely a development of the past ten years, are usually located on suburban tracts of ten to twenty acres, though where large numbers of fowls are kept, this acreage must be extended. The high price of land near towns and cities emphasizes the need of economy in the amount used. In some cases, no provision for an outside yard is made, the fowls being confined in the house all of the time. The same plan is sometimes followed where there is sufficient land for outside yards, but the soil is of such a character that during the winter season the yards are wet and muddy. With such soil and restricted yards it is a question whether yards are any advantage during the rainy season, or whether the fowls are not better kept in the house all of the time.

A number of poultrymen are now keeping their laying flocks confined in houses throughout the year. Others keep them confined only during the wet season. Experiments made at this Station a few years ago indicated that a satisfactory egg yield can be secured where the fowls are confined in the house throughout the year.

These results are supported by the records of several small pens of the station flock. In 1914-15 a pen of twenty-four Oregons were kept shut in a small house 8 by 12 feet throughout the year, and they made a record of 229.16 eggs a hen. This is ten eggs a hen more than were laid by a larger pen that had the liberty of a roomy yard every day in the year.

In 1915-16 a pen of twenty-five Barred Rock pullets were confined in a house throughout the year, and they laid an average of 182.6 eggs a hen, practically the same production as our experimental flocks of the same breeding. The production was as follows by month per hen:

	1915-16	1914-15
October	....	1.66
November	1.10	6.75
December	10.10	17.45
January	13.65	18.95
February	16.85	20.54
March	22.60	23.50
April	22.80	22.95
May	20.50	21.95
June	17.45	18.54
July	17.10	19.58
August	15.10	18.79
September	12.40	16.20
October	7.90	15.20
November	4.25	6.62
December	.70	.20
Average	182.6	229.16

The annual average is for the twelve months beginning with first egg laid by each hen.

Another pen of twenty-five Oregons confined throughout the year 1915-16 in a house 10 by 14 on the writer's back-yard lot, made an average of 216 eggs a hen, though the feeding was not particularly favorable. In each case they had plenty of fresh air and were fed in such a way as to induce maximum exercise.

These three flocks were of the Station's high-producing strain. Where the fowls have plenty of exercise and right feeding there appears to be little difference in the yield, whether confined or on range. In other words, wide range out of doors is not necessarily essential to high production.

This has no relation, however, to the other problem of fertility and hatching quality of the egg. As to what effect close confinement has on the breeding quality of the stock has not yet been determined definitely, but the best information available points to the necessity of giving the breeding stock plenty of good range. The cumulative effect of continuous confinement of breeding stock, generation after generation, is likely to result in lowered vigor. Very few breeders confine breeding stock.

YARDS

If the poultry houses are located near a neighbor's field or gardens it will be necessary to yard the fowls. For other reasons, such as the keeping of more than one variety or strain of fowls, separate fenced enclosures must be maintained.

Keep the Yards Clean. When chickens are confined in yards throughout the year, care must be taken to keep the yards clean, otherwise in time there will be serious losses from diseases and general lowering of vitality. The yards sooner or later become contaminated with disease-producing germs, and losses through sickness and decreased vitality will render it unprofitable to keep fowls. Dr. Salmon says: "Accumulations of excrement harbor parasites, vitiate the atmosphere, and breed contagion." It may be possible to keep yards sufficiently clean by disinfection and other means to prevent troubles of this kind, though this is doubtful. At any rate, the expense of disinfection and cleaning would render it impracticable.

Size of Yards. The larger the yards the more exercise the fowls will take. The fowls will do better in a large yard than in a small one, even though the same number of square feet be allowed each fowl, because there is more room for exercise. Each fowl has the use of the whole yard whether it be large or small. The cost of fencing will largely govern the size of the yard. Fencing is expensive, and if the yards are very large the cost may exceed that of the houses. For a pen of 100 fowls a yard 100 by 100 feet is a good size.

Double Yards. In order to give the fowls clean ground and guard against "ground poisoning," the best plan is to have double yards; that is, two yards for each pen of fowls. If one long continuous house be used and it is divided into small pens, it will be better to have the yards on each side of the house, rather than two yards on one side, thus obtaining width enough in the yards for cultivation. Where the yards are too small for horse cultivation, spading will have to be resorted to.

Separate Houses. Under some conditions and for special breeding pens, a more convenient arrangement than one long house is to use small separate houses, placed in a row 20 feet apart. By this arrangement the yards may all be on one side of the house, and one can walk or drive a team on the other side from one end to the other without opening gates. Another advantage is that there is less danger of contagious diseases spreading from one flock to another than in the continuous house; every flock is practically isolated from the other.

Cultivation of Yards. The cultivation and cropping of the yards will keep them in good condition. The crops will use up the manure and lessen the danger from spreading of disease. The cultivation also keeps the surface of the soil loose; unless cultivated, the soil, if of clayey nature, will become hard and baked from continuous use. The expense of building the extra fence for the double yards will be offset by the value of the crops that may be grown on the vacant yards. It will pay to plow the yards two or three times during the year. Cultivation has a double purpose; first, it cleans the yards; second, it offers the fowls more exercise.

Crops to Grow. Different kinds of crops or vegetables may be grown on the vacant yards. Green food may be grown for the fowls, or vegetables may be grown for the family. The droppings of the fowls will keep the soil in a very productive condition. If it is not desired to use the yards for garden purposes, such crops as vetch, alfalfa, clover, kale, rye, etc., may be grown. Where it grows well, clover may be planted early in the spring and the chickens turned onto it in the fall. Vetch sown in the fall will furnish a great quantity of excellent green food in the spring and summer. Where it thrives, probably no other forage plant will furnish more green food to the acre than thousand-headed kale. If planted early in the spring, it will furnish a great quantity of green food in the fall and following winter. Rye sown in the fall will make considerable green food in the following spring and summer.

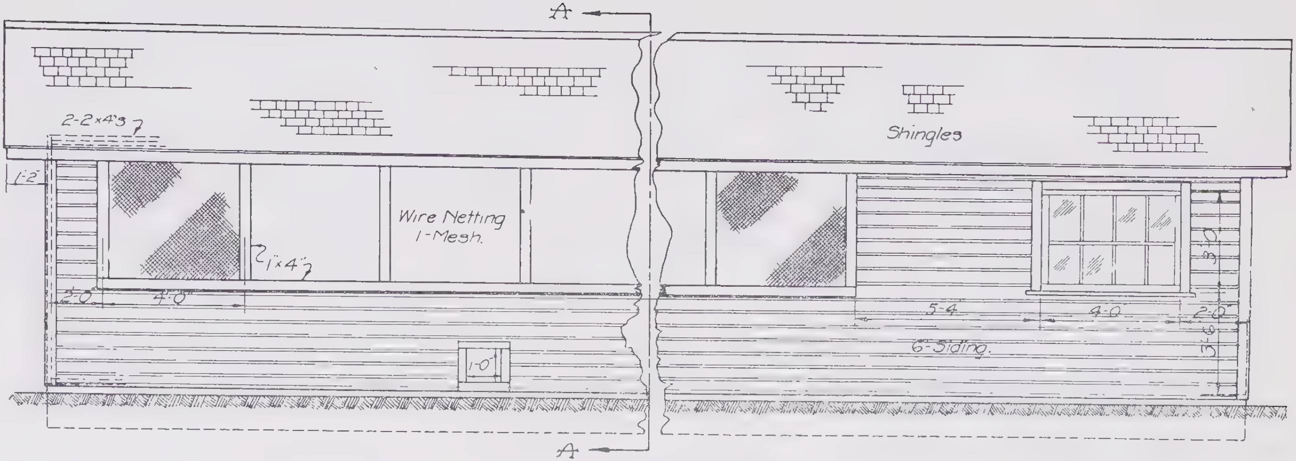


Fig. 9. Front elevation, 500-hen house.

Shade. For fowls in summer shade is very necessary. This may be secured from fruit trees or other trees. Two or three fruit trees, such trees as will do best in the particular soil and location, in each yard, will furnish some revenue as well as shade. Most varieties of fruit do well in poultry yards. Plums, apples, and cherries do especially well. The droppings fertilize the trees, and the poultry aid materially in keeping in check certain of the fruit pests. Sour apples should be fed sparingly to fowls. Where it is not desired to plant trees, sunflowers or corn may be planted early in the season in a part of the yard fenced off temporarily.

COMMERCIAL UNITS

In commercial poultry keeping a desirable plan for housing is to build in 500-hen units. As the size of the flock is increased the production is decreased per hen, other things being equal. On the other hand, the larger the unit, the lower the labor costs in feeding and general care. Under certain conditions the saving in cost in the larger units may more than offset the decrease in production. If there is good management there may be little difference in the final returns from the 500-hen units and the 1000-hen units. If the proper yard space is available we recommend the smaller units.

Range. As to the amount of range and the character of the soil, in general the more good range the fowls have the better will be their health and production. Where the soil is sufficiently dry and porous the fowls for best results should have the use of a roomy yard. For a flock of 500 hens a good plan is to set aside two acres, using one acre at a time and growing a crop on the second acre. It is not very material whether the land is all in front of the house, divided into two yards, or whether one yard is in front and the other at the rear of the house. In any event there should be double yards. • A more ideal condition would be three yards so that each yard is vacant two years out of three. This will insure better sanitary conditions and greater freedom from contagious diseases.

Close Confinement. If the land lacks drainage and the soil is heavy, which means muddy, wet yards all winter in Western Oregon, it is just as well to keep the hens shut in the house all winter. The same practice should be followed in Eastern Oregon where the snow covers the ground for several months in the year. If the fowls get the proper feed and care the production will be just as good as if they had the liberty of outdoors. The ideal condition, however, if the soil is of the right character, is outdoor range all the year.

For permanent results there is no doubt that it is advisable to give the maximum amount of range consistent with overhead costs. If the land is not of too high value it will pay to give four or five acres to 500 hens. By the growing of crops on the vacant yards, the overhead charge need not be much greater for the four acres than for the two. The conditions would then be favorable not only for good egg production but also for keeping the stock in good breeding condition.

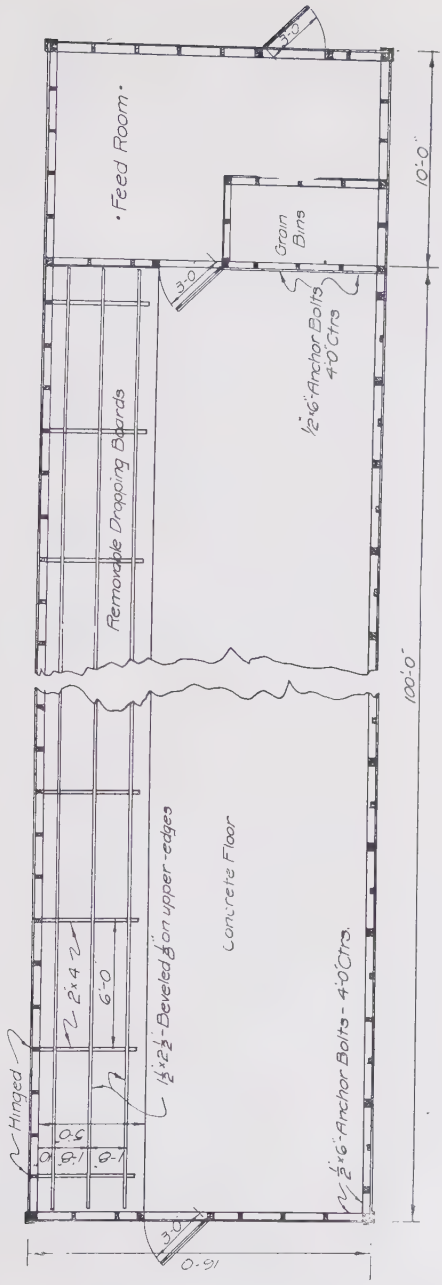

3'-0"
Feed Room
Grain Bins
10'-0"
3'-0"
1/2"×6" Anchor Bolts 4'-0" Ctrs
Removable Dropping Boards
100'-0"
Concrete Floor
1½"×2½" Beveled ⅛" on upper edges
2×4
6'-0"
Hinged
5'-0"
1'-0"
1'-8"
1'-8"
1/2"×6" Anchor Bolts - 4'-0" Ctrs.
3'-0"
16'-0"

Fig. 10. Floor plan, 500-hen house.

FIVE-HUNDRED-HEN HOUSE

The style of house illustrated herewith will be suitable for Western Oregon and in general for sections of the State where the temperature does not get much below zero. There is no reason why in Western and Southern Oregon the open-front house can not be used throughout the year.

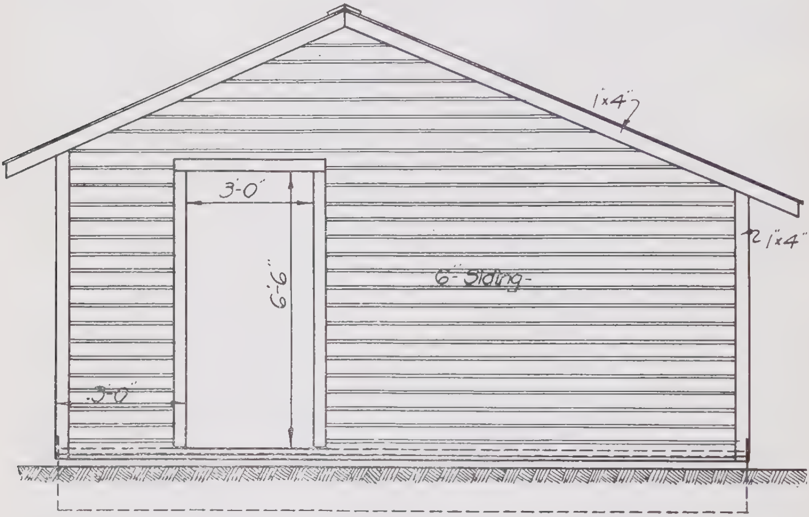


Fig. 11. End view, 500-hen house.

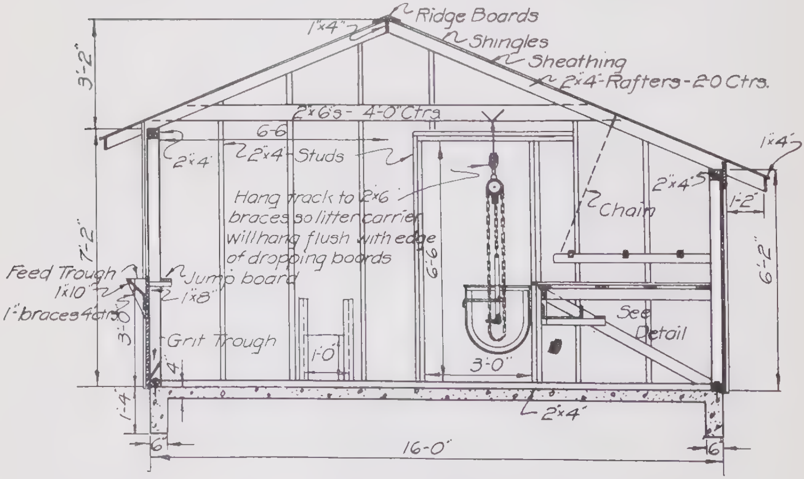
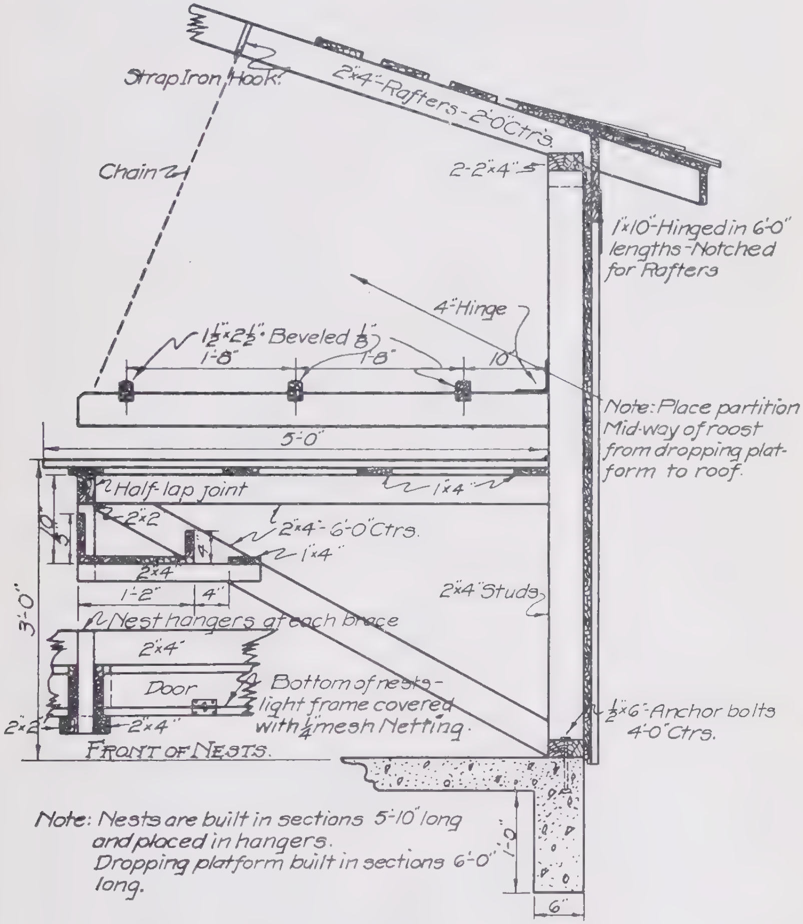


Fig. 12. Section AA, 500-hen house.

The fowls will be more comfortable on the floor if they are protected from draft in the colder months by closing the opening at the bottom of the wall three feet, but not more. If this is extended too high, there will not be sufficient light in the house. As to the size of the opening, the drawing shows a front wall of 7 feet 2 inches, which is boarded up 3 feet from the bottom, leaving 4 feet of opening. This will be ample.


Strap Iron Hook
2"×4" Rafters - 2'-0" Ctrs.
Chain
2-2"×4"s
1"×10" Hinged in 6'-0" lengths - Notched for Rafters
4" Hinge
1½"×2½" Beveled ⅛"
1'-8"
1'-8"
10"
5'-0"
Half-lap joint
1"×4"
2"×2
10
3
2"×4" - 6'-0" Ctrs.
4
1"×4"
2"×4
1'-2"
4"
2"×4" Studs
Nest hangers at each brace
2"×4"
3'-0"
Door
Bottom of nests - light frame covered with ¼" mesh Netting.
2"×2
2"×4"
½"×6" Anchor bolts 4'-0" Ctrs.
FRONT OF NESTS.
1'-0"
6"

Note: Place partition Mid-way of roost from dropping platform to roof.

Note: Nests are built in sections 5'-10" long and placed in hangers. Dropping platform built in sections 6'-0" long.

Fig. 13. Section of rear wall and roost, 500-hen house.

In the cold sections of the State, it will be better to modify the plan by placing three windows in the front, one at each end and one at the center for light and covering the rest of the opening with muslin during the cold weather. The windows should be on hinges so that they may be opened on warm days and in summer they may be removed altogether.

In Western Oregon, where the prevailing winds come from the south or southwest, the house should face the east or southeast. In other sections where the direction of these winds is different, the house may be faced toward the south.

As to the dimensions of the house, 16 feet wide and 100 feet long is a good size for 500 hens. There is no particular objection to making it 18 feet or 20 feet wide and cutting off on the length, but with a house deep in proportion to length the supply of fresh air is not so well distributed, and there is less fresh air for the fowls at night. They are crowded more together, and to that extent the full benefit of the open-front is not obtained.

The difference in the cost of construction of the house of 16-, 18- or 20-foot width is negligible and need not be considered seriously. It is important that the fowls have plenty of fresh air at night as well as during the day and this condition cannot be secured where the roost perches are placed very close together. This house calls for three perches the length of the house, placed eighteen inches apart or twenty inches from center to center. This allows roost space of about 7 inches a hen. In a twenty-foot house eighty feet long, which would give the same floor space as 16 by 100, it will be necessary to have four roost perches instead of three; this means a greater congestion of the hens at night and consequently more impure air for them to breathe. By placing the roosts far enough apart, this objection will be offset to some extent. Again, a wide house with a wide roosting platform makes it difficult for the poultry keeper to catch the fowls on the rear perches.

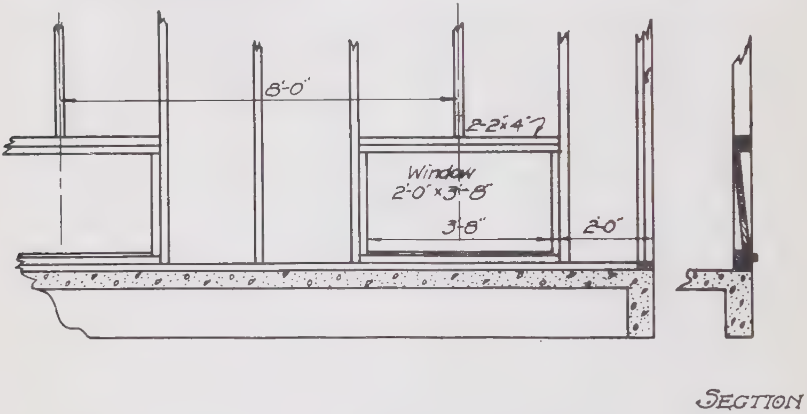


Fig. 14. Window framing, in rear wall, 500-hen house.

Rear Windows. Under certain conditions, windows in the rear of the house under the roost platform are an advantage, since they light up the floor better. It is asserted that such windows are necessary so as to prevent the fowls from scratching the litter under the platform, the theory being that a hen when scratching turns her head to the light. Details for these windows are shown in the plans. Their use is left optional. Where the house faces the east and is well lighted from the front, there are some disadvantages in the windows. With windows in the west side, the sun shining through them in the summer days will make the house uncomfortably warm. This objection may be obviated to some extent by leaving the windows partly open and by whitewashing the windows. There is also the extra cost of the windows. The argument that without the windows the litter will pile up under the roost platform at the rear is of no great importance. With a well-lighted floor and proper care in throwing the grain in the litter, there will be no trouble from this source. Where the house faces south, there will be no objection to the rear windows except the cost, and under certain conditions where the light is not good the windows will be an advantage.

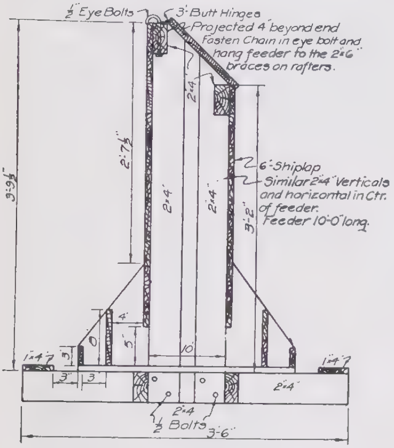


Fig. 15. Section of feed hopper.

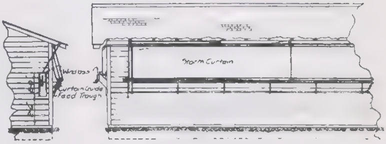


Fig. 16. Floor plan of feed hopper.

Rear Ventilation. Provision is made in the drawing for ventilation over the roost platform above the plate by means of hinged 1-by-10 inch boards in 6-foot lengths, notched for the rafters. These boards should be closed during cold weather and open only during warm weather.

The Roof. In the drawing a shingle roof is shown; this is the most permanent type of roof. A good quality of roofing paper, also satisfactory, costs less than shingles. With paper, a flatter roof is just as satisfactory as the steeper roof necessary for shingles.

Feed Hopper. A dry mash hopper, ten feet long and ten inches wide, is detailed. This is suspended lengthwise of the house, from the 2-by-6-inch ties for rafters. The sides of this hopper are vertical and the hens eat from both sides. The whole hopper is used for dry mash and there are no partitions in it. A trough for grit, charcoal, shell, etc., is easily provided between the 2-by-4 studding on the three-foot front wall and just the width of the studding. This should be high enough from the floor to prevent litter being scratched into it. If the bottom is laid on cleats and the front hinged, this trough will make it more easily cleaned out.

Moist Mash Trough. Where moist mash is fed, a feeding trough may be attached to the front wall at the top. This trough may also be used for green stuff. (A good way to feed kale, however, is to hang up the whole plant in the house, on a wire suspended from the rafter or rafter braces.) The hens eat out of the trough through a graduated mesh wire used to cover the open front with the wide mesh at the bottom. This trough should be no higher than the three-foot front, the outer board being hinged at the bottom to facilitate cleaning. A four-inch jump board on which the hens stand while eating extends the length of the house. This board should be removable so that when pullets are first put into the house, the board can be taken down at night until they have become accustomed to go to the perches.

Litter Carrier. A litter carrier is shown on the plan. For large houses, this will be an advantage in removing the droppings. The carrier hangs flush with the ends of the dropping board, so that the droppings are scraped into the carrier. The track may extend out through the end of the house, the manure being dropped into a cart or into a manure shed. When not in use, the carrier can be pushed back into the feed room.

Watering. In Western Oregon, where the temperature is mild, water can be piped into the house. A good plan is to use an ordinary pail or pails with an automatic shut-off. These should be placed up about two feet from the floor in the center of a platform made of slats or wire. The same arrangement can be made for the feeding of buttermilk. In cold sections, this system cannot be used on account of the water pipes freezing in the winter time. In such sections, it will be a good plan to have a small heater in the feed room for heating water.

The Roosts. The roosts are made in a frame, hinged to the studding at the rear and suspended by chains from the rafters at the front. The platforms are in sections six feet long, and are removable.

The Nests. The plan shows detail of nest under the platform. These nests are built in sections five feet ten inches long, and placed in hangers. The bottom of the nest is made of galvanized wire cloth for fruit driers, ¼-inch mesh, in preference to boards, to prevent breakage of eggs. The hen enters the nest from the rear, and the front is closed by a board, hinged at the bottom, which is let down when the eggs are gathered. There are no partitions for separate nests. A number of hens lay together in one section. This makes a nest of simple construction, easily kept clean and free from mites.

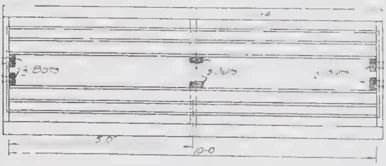


Fig. 17. Controlling apparatus of storm curtain.

Roller Curtains. Under certain conditions, an adjustable curtain is desirable. For this purpose, a roller curtain such as that designed by Shoup of the Western Washington Station is very convenient. This curtain may be raised or lowered in a few seconds, by turning a crank at one end. A detail of the Shoup curtain is given herewith. In the mild climate of Western Oregon, the writer does not recommend the use of the curtain. With the house faced away from the prevailing winds and storms, there will seldom be any need for the curtain. In the unusual severe weather, such as that of December, 1919, a curtain would have been a decided advantage for two or three nights, but such weather may not come again in a generation. Many poultrymen avoided serious loss during the zero weather by covering up the opening with burlap or muslin. The danger from the curtain is that it may be closed when it should be open, and open when it should be closed. A stationary curtain and glass windows may be the best arrangement for the cold sections.

BILL OF MATERIAL FOR 500-HEN HOUSE

Description	Size	No. Req'd.	Description	Size	No. Req'd.
Rafters	2″x4″x12′	56	Feeder	1″x4″x10′	2
Rafters	2″x4″x10′	56	Feeder	1″x3″x10′	2
Sheathing	1″x6″	3500	Feeder	1″x8″x10′	2
		Lin. ft.	Feeder	1″x13″x14′	1
Shingles		18,500	Feeder ship-lap		94
Studs	2″x4″x12′	35			Bd. ft.
Studs	2″x4″x14′	28	Finishing	1″x4″x14′	5
Studs	2″x4″x22′	4	Ridge Board	1″x4″x16′	43
Studs	2″x4″x10′	7	Corner Bds., etc.	1″x4″x12′	2
Studs	2″x4″x16′	7	Corner Bds., etc.	1″x4″x10′	2
Purlin	2″x4″x22′	20	Corner Bds., etc.	1″x6″x16′	8
Sills	2″x4″x16′	16	Corner Bds., etc.	1″x10″x12′	10
Rafter Br.	2″x6″x14′	28	Nests	2″x4″x12′	3
Sideing	1″x6″	1350	Nests	2″x2″x12′	5
		Bd. ft.	Nests	1″x3″x12′	29
Roost and)	2″x4″x18′	14	Nests	1″x4″x12′	17
Dropping)	2″x4″x20′	9	1 window 3′x4′		
Boards)	1½″x2½″x16′	15	3 doors 3′x6′-6″		
Roost and)	1½″x2½″x20′	3			
Dropping)	1″x4″x12′	3			
Boards) ship-lap		500			
		Bd. ft.			
Feeder	2″x4″x12′	5			
Feeder	2″x4″x10′	2			

BILL OF MATERIAL

Hardware

Nails—20d—40 ℔s.
  8d common 75 ℔s.
  8d Case—25 ℔s.
  Shingle—116 ℔s.

Bolts—½″x6″ Anchor bolts—40
  ½″x4½″ for feeder—10
  ½″x4½″ eye bolts for feeder—4

Hinges—16 pair—3″—for ventilating boards
  10 pair 6″ for roost
  17 pair 2½″ butt hinges for nests
  1 pair 2½″ butt hinges for feeders

Chain—75′ light chain for roost
  8′ (3/16″ wire) chain for feeder

*Wire netting—1″ mesh 4′x96′ for open front
  Galv. wire fruit drier cloth—¼″ mesh 1′x100′

Floor
  Concrete work (1:2.5:5 mixture. 1:2 wearing surface)
  Cement—35 bbl. Portland
  Sand—12.5 cu. yd.
  Stone or Gravel—25 cu. yd.

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*Use graduated mesh wire with 4″ mesh at bottom if moist mash trough is used.

Note: This bill does not contain material for windows in rear or any fixtures in feed room.

Station Bulletin 180 August, 1921

Oregon Agricultural College

Experiment Station

Department of Poultry Husbandry

Egg-Laying Characteristics of the Hen

By

JAMES DRYDEN

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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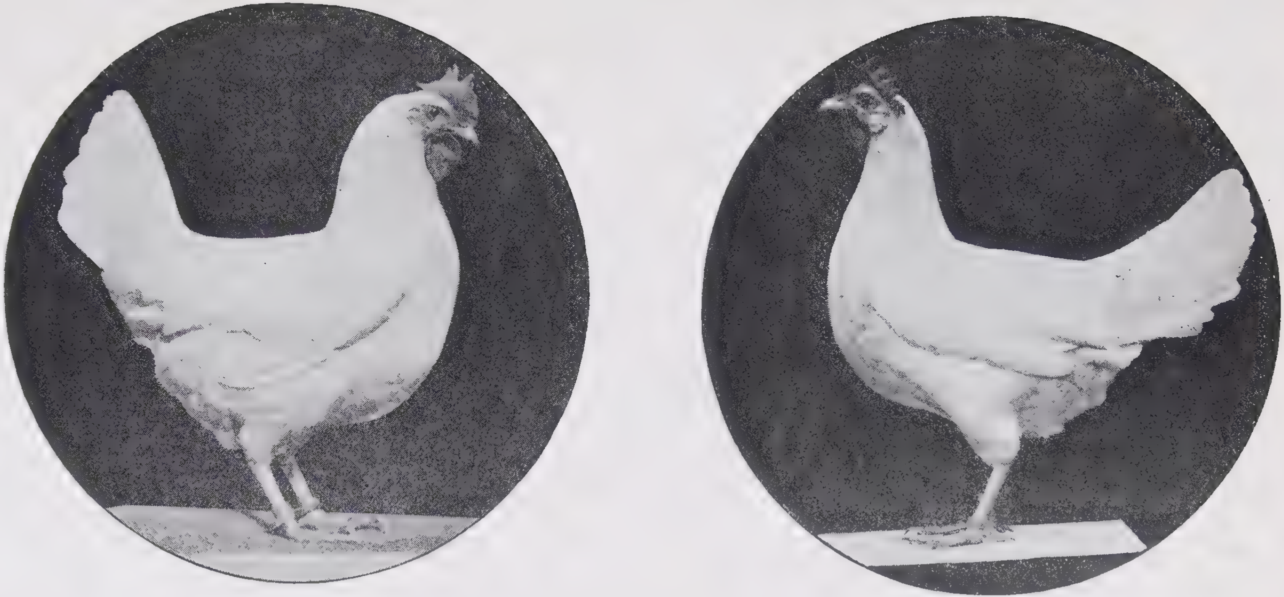


Fig. 1. At left, C521 (Lady MacDuff) representing the Station's "Oregons." The first hen in the world with trap-nest record of 300 eggs in a year. Her record was 303. At right, hen A27, representing the Station's White Leghorns; the first hen in the world to make trap-nest record of 1000 eggs in lifetime. Her complete record was 1188 eggs. All the Station's Oregons and Leghorns have more or less of the blood of these two hens, which have thousands of descendants throughout the country.

The main conclusions drawn from the experiments reported in this bulletin are:

1. High fecundity is inherited.

2. Selection of breeding stock on the basis of annual trap-nest records regardless of prepotency or tested qualities, is a certain method of increasing egg production.

3. Some hens and some males have the power of transmitting high fecundity; others have not this power. Therefore more rapid progress will be made in increasing the production of the strain if only those hens and those males be used in the breeding pens that have shown by the egg records of their pullets, or by the progeny test, that they possess the power of transmitting high egg production.

Egg-Laying Characteristics of the Hen

INTRODUCTION

When poultry breeding experiments were started at this Station, twelve years ago, there was considerable discussion as to the effect of selective breeding in increasing egg production. Doubt was frequently expressed as to the possibility of increasing production by selection of breeding stock on the basis of trap-nest records of production. There had been no sufficient demonstration of the fact of transmission of high egg-laying qualities. There was some evidence that the contrary was true. At the Maine station, after nine years of experiments the results as reported were largely negative in character. There had been apparently no increase in production. Beyond that there was little literature on the subject embodying conclusive data.

It was agreed that the subject required further investigation. It was highly important from the standpoint of the poultry producer, as well as from the standpoint of the consumer of poultry products, that production be increased. The costs of egg production were high, and unless they could be reduced, poultry keeping would continue to be a business of hazard.

Previous experiments by the writer had shown a wide variation in individual production, and if it should prove that those variations were inherited, it would seem then, that proper breeding, by increasing production, would be of great importance in lowering the costs.

At that time the flocks of the United States as an average laid fewer than seventy-five eggs a year per hen, while trap-nest records showed yields exceeding two hundred a hen and others less than two dozen a hen, even within the same breed and under similar conditions of care. This fact indicated great possibilities for the poultry industry, should it be proved that those variations were inherited. The production of the hens of the United States as given is based on census figures; these apply to hens of all breeds and different ages and would not be fully comparable with the production of pullets, or the first year's production.

Until the invention of the trap-nest, poultry breeding, so far as egg production was concerned, was an uncertain business because the poultryman had no means of knowing which were the best layers in his flock. With the trap-nest it was then possible to attack the problem of increasing production in a practical, scientific way.

Our breeding work began in the fall of 1908 and has continued without intermission up until this time, though the scope of investigations has been necessarily limited. With the funds and help available, it has not been possible to cover as many closely related problems as was desired. Breeding work is necessarily slow, and often disappointing because of the variety of conditions under which the flocks are kept during the long period of experiment. Egg production fluctuates greatly as the environmental conditions vary. Changes in the weather affect the egg yield, and it is impossible so to regulate other conditions that the yield is not appreciably affected by sudden temperature and other changes in the weather. Where the results depend upon comparisons extending over several years, with flocks of different generations, this is a disturbing element that can possibly be overcome only by long-continued, carefully conducted experiments.

While the feed rations and methods of feeding can be fairly well controlled, there will be unavoidable differences. It is not always possible to get the same quality of feed, year after year. Another limiting factor is diseases. To maintain a strict quarantine so that the flocks of one year will show as great freedom from diseases as those of another, is possible only in part. Change in the attendant who feeds, tends trap-nests, and does other necessary work in the poultry yards, also has its influence on production. Change of attendant is sometimes unavoidable.

Another factor, probably the most difficult to control of any, is that of the hatching and rearing of the chicks. The vigor of the chicks is influenced by the care and feeding of the breeding stock, by the methods of hatching, and by the brooding and feeding of the chicks. Any difference in the vigor of the hen will be reflected in the egg yield. The date of hatching, or the date at which the pullet comes to laying maturity, is another factor that has a decided influence on the first year's production.

It is thus impossible so to control all these and other environmental conditions that we can know with mathematical definiteness that the egg producion of one particular generation of fowls for any stated period measures with absolute certainty the laying capacity of the flock.

Nor is it essential that the environmental factors actually be the same year after year to prove by the egg records for the year the transmission of high fecundity. With a sufficient number of individuals, and a sufficient number of generations, the fact will be proved if there is a consistent and marked increase, even though the conditions may and must vary, year after year.

Scientific demonstration need not and can not depend upon mathematical and mechanical control of environmental factors. At the same time it must be conceded that the degree of success in controlling these conditions will measure very largely the success of the breeding experiment.

PROBLEMS OUTLINED

The general subject of investigation is the inheritance of egg-laying characteristics of the hen, covering the following related problems:

(1) Is high fecundity inherited?

(2) Relation of short-period production, or rate of laying, to the annual and biennial record of the hen.

(3) Does the first year's production indicate the capacity of the hen in subsequent years?

(4) Will selection on the basis of high annual or short-period production increase the profitable life of the hen?

(5) Correlation between early laying maturity of the pullet and high fecundity.

(6) Correlation between late laying and high fecundity.

(7) The effect of inbreeding on vigor and productive qualities.

(8) The relative influence of sire and dam on the egg production of the offspring.

(9) Correlation between type of hen and egg production.

(10) Correlation between rate of laying and composition of the egg.

This bulletin is confined to a study of our breeding records bearing on the first four problems enumerated above. Later bulletins will report work on the other problems.

There is also included in this bulletin a report of a preliminary nature on the tenth problem, the correlation between rate of laying and composition of the egg.

THE PLAN

For the experiments, Barred Plymouth Rocks and White Leghorns were chosen, the former because they are a variety of an American breed, very popular on the farms for general purposes, the latter because they are the most popular breed on commercial egg farms. A cross between these breeds was made, as a check on the others, because there is a somewhat widespread conviction that some of the pure-breds through close breeding have lost more or less vigor, and that a cross will restore the vigor. If therefore, the cross gave a better egg yield than the pure-breds it would be strong circumstantial evidence that the pure-breds lacked in vigor. Then, if after several generations the cross-bred birds showed an increase in production, while a similar increase was shown in the pure-breds it would be strong evidence that the breeding was effective, and that high fecundity was inherited. On the other hand, without the cross-bred check it might be questionable, whether the increase in the pure-bred was not due solely to increased vigor, which might be secured from proper mating and breeding. It is known that vigor and production are closely related.

IS HIGH FECUNDITY INHERITED?

A flock of 113 Barred Plymouth Rock pullets were purchased from six different breeders in Oregon, and 63 White Leghorn pullets from several Oregon poultrymen. These pullets were put into their houses early in the fall of 1908. The houses used were new, portable, open-front, or colony houses, eight by twelve feet in size. The fowls had the liberty of roomy yards at all seasons. The hen doors in the houses were open at all times. The double-yard system was used and the houses were moved once a year onto clean ground. The same style of house and the same system of yarding were used in all the years of the experiment. The same system of feeding was followed, as nearly as possible, throughout the experiment. Inbreeding was avoided, and practically no new blood was added. In the last three or four years, however, especially in the case of the Leghorn, the blood lines had become closely drawn, so that in the case of the Leghorn the results of the later years are not properly comparable with those of former years.

It was aimed to use each year in experiments only pullets that were mature and about ready to lay by November 1, so that the egg records of different years might afford a fair basis of comparison. This practice, however, could not be followed arbitrarily. It was not always possible to hatch them at the same time, and where the purpose was to hatch as many chicks from certain hens as possible, the date of hatching must vary more or less. Any of the yards or hens that were used in our comparisons, however, did not vary greatly in date of laying maturity. On this account and for other reasons, the number of pullets used in the tabulation for some of the years is rather small. It is believed, however, that enough individuals have been used to make it possible to form conclusions on the subject of investigation.

The capacity of a hen is commonly measured by her annual egg yield, and the proof of transmission is shown if the female progeny produces not necessarily as many eggs as the parent, but a certain increase over the average production of the unbred flock or breed. It may be true, however, that her real capacity is better shown in shorter periods of production, because in shorter periods, environmental conditions are under better control. Our records, therefore, will be studied from annual records, as well as longer and shorter periods.

Artificial lighting was not used in these experiments. It had not come into use when the experiments were started, and to have adopted it in later years would have introduced a factor that would render impossible proper interpretation of results of different generations, if some were under artificial lights and some were not.

In all experiments the first year begins on the date the first egg was laid, and ends twelve months from that date. The second year begins at the end of the first laying year. In all cases, hens that died before the year was completed are not included, except that a record of number died is given.

Eggs laid on the floor or outside of the trap-nests are added to the total production of the flock and show in the yard average, but not in the individual-hen records.

RESULTS WITH BARRED PLYMOUTH ROCKS

First Generation or Foundation Stock. In the case of Barred Plymouth Rocks ninety-two hens are used in the experiment relating to inheritance of fecundity. For these there is a complete record for the first year's production.

The first and most significant thing in the production of all the years is the wide variation in the records of individual hens. This applies to the two different breeds, as well as the crosses. In the original flock of ninety-two Barred Rocks this variation, as shown in Table 1, extends from 218 eggs as the highest to 6 as the lowest, the average of all being 82.67, or including eggs laid outside of trap-nests, 86.14 eggs. In other words, between the highest and lowest record there is a range of 212 eggs. It will be noted that there is a gradual drop all of the way down from the highest to the lowest. A column is added giving the best two-months record of each hen. The significance of this record will be discussed on a later page.

Second Generation. The production in the second year, 1909-10, is given in Table II, for yard 6, 28 hens. These were hatched from the first-year flocks but without selection, and sired by males of pedigree of unknown production. In this case the highest record was 183 and the lowest 60, a range between highest and lowest of 123. The yard possibly would represent a better average of the production of strain or strains than the original flock, or rather make a better starting point in studying the effect of breeding, because the pullets of this yard were raised on the Station plant, and so far as the hatching and rearing are

TABLE I. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yards 4 and 5, 1908-09, Barred Plymouth Rocks.

Hen No.	Production		Hen No.	Production		Hen No.	Production	
	1st year	Best 2 months		1st year	Best 2 months		1st year	Best 2 months
1....	36	10	35....	66	37	78....	68	30
2....	93	28	36....	70	30	80....	71	20
3....	105	32	37....	47	18	81....	39	29
4....	124	26	40....	183	47	82....	61	29
5....	131	44	41....	118	45	83....	45	22
6....	80	27	43....	105	44	84....	56	23
7....	47	19	44....	59	28	86....	106	34
8....	67	28	45....	140	46	87....	64	30
9....	51	25	47....	82	36	88....	82	33
10....	88	28	48....	47	29	89....	153	35
11....	31	15	50....	91	45	90....	83	43
12....	72	27	51....	115	41	91....	49	22
13....	71	28	52....	70	26	93....	80	32
15....	155	38	53....	83	45	95....	134	41
17....	51	27	54....	112	46	96....	64	35
18....	33	14	55....	57	28	97....	100	32
19....	73	32	56....	141	42	98....	81	29
20....	65	24	57....	59	31	99....	167	48
21....	57	28	58....	37	22	201....	52	30
22....	6	3	61....	85	31	202....	103	37
23....	74	31	62....	106	31	203....	96	44
25....	69	28	64....	49	23	204....	101	36
26....	74	38	65....	218	50	205....	59	23
27....	68	31	66....	74	33	207....	150	47
28....	27	20	67....	86	28	208....	52	26
29....	42	22	68....	78	24	209....	53	21
30....	84	41	70....	133	36	210....	58	30
31....	93	33	72....	67	25	211....	160	48
32....	136	40	73....	66	24	212....	46	34
33....	131	37	74....	76	32	213....	84	36
34....	76	25	77....	89	28			
Average of yard........							82.67	31.29
Unidenitfied eggs added........							86.14	

TABLE II. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 6, 1909-10, Barred Plymouth Rocks.

Hen No.	Production		Hen No.	Production		Hen No.	Production	
	1st year	Best 2 months		1st year	Best 2 months		1st year	Best 2 months
201....	104	33	211....	167	43	221....	103	32
202....	128	41	212....	138	30	222....	140	44
203....	114	31	213....	144	37	223....	60	32
204....	183	40	214....	115	37	224....	138	43
205....	88	28	215....	134	31	225....	102	33
206....	85	37	216....	104	34	226....	160	38
207....	169	43	218....	76	24	227....	76	28
208....	76	25	219....	88	27	228....	104	28
209....	179	33	220....	110	25	229....	75	29
210....	134	38						
Average of yard........							117.64	33.71
Unidentified eggs added........							120.68	

TABLE III. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 15, 1910-11, Barred Plymouth Rocks.

Hen No.	Production		Hen No.	Production		Hen No.	Production	
	1st year	Best 2 months		1st year	Best 2 months		1st year	Best 2 months
A 75	158	40	A 92	144	38	A 106	202	44
A 76	183	43	A 93	201	42	A 107	122	33
A 77	214	50	A 94	20	8	A 108	166	37
A 78	215	44	A 95	138	31	A 109	179	41
A 79	219	50	A 96	204	43	A 110	175	35
A 80	168	40	A 97	79	26	A 111	204	53
A 81	203	42	A 98	130	35	A 113	175	37
A 83	167	37	A 99	134	33	A 115	188	39
A 84	44	28	A 100	125	42	A 116	218	50
A 85	182	43	A 101	137	37	A 118	191	45
A 86	133	35	A 102	169	39	A 119	156	42
A 87	6	6	A 103	168	37	A 120	148	41
A 88	187	45	A 104	158	35	A 121	168	39
A 91	158	36	A 105	200	46	A 122	259	49
Average of yard							161.78	38.48
Unidentified eggs added							164.28	

TABLE IV. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 6, 1912-13, Barred Plymouth Rocks.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
C 32	188	50	A 78	213	....	....	207	169
C 33	139	36	A 111	204	....	....	65	218
C 34	180	42	A 81	203	....	....	207	169
C 35	225	53	A 79	219	....	....	207	169
C 36	89	34	A 81	203	....	....	207	169
C 37	199	47	A 79	219	....	....	207	169
C 38	213	49	A 111	204	....	....	65	218
C 39	143	49	A 111	204	....	....	65	218
C 40	151	39	A 77	214	....	....	65	218
C 41	177	45	A 79	219	....	....	207	169
C 42	138	45	A 111	204	....	....	65	218
C 43	142	41	A 81	203	....	....	207	169
C 44	227	49	A 111	204	....	....	65	218
C 45	171	46	A 81	203	....	....	207	169
C 46	201	41	A 77	214	....	....	65	218
C 47	156	41	A 81	203	....	....	207	169
C 48	268	51	A 111	204	....	....	65	218
C 49	194	44	A 79	219	....	....	207	169
C 50	224	53	A 77	214	....	....	65	218
C 51	196	56	A 111	204	....	....	65	218
C 52	157	52	A 77	214	....	....	65	218
C 53	144	43	A 81	203	....	....	207	169
C 54	186	49	A 79	219	....	....	207	169
C 55	142	47	A 111	204	....	....	65	218
C 56	210	50	A 111	204	....	....	65	218
C 57	178	44	A 77	214	....	....	65	218
C 58	205	55	A 77	214	....	....	65	218
C 59	209	41	A 79	219	....	....	207	169
C 60	3	2	A 111	204	....	....	65	218
C 62	175	45	A 78	213	....	....	207	169
C 63	140	38	A 77	214	....	....	65	218
C 64	235	50	A 122	259	....	....	207	169
C 65	123	39	A 81	203	....	....	207	169
C 67	187	44	A 111	204	....	....	65	218
C 68	147	45	A 78	213	....	....	207	169
C 69	232	55	A 77	214	....	....	65	218
C 70	152	50	A 77	214	....	....	65	218
C 149	171	40	A 78	213	....	....	207	169
①	174.13	44.74		210.94				194.79
②	178.16							

① Average of yard. ② Unidentified eggs added.

TABLE V. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 7, 1912-13, Barred Plymouth Rocks.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
C 72	155	43	207	169	....	....	65	218
C 73	207	51	204	183	....	....	65	218
C 75	172	43	207	169	....	....	65	218
C 76	198	42	B 154	191	204	183	207	169
C 77	163	42	....	....	....	....	......	....
C 78	199	45	A 116	218	65	218	207	169
C 79	201	46	207	169	....	....	65	218
C 80	202	51	....	....	....	....	......	....
C 81	180	39	B 150	105	A 116	218	207	169
C 82	200	43	....	....	....	....	......	....
C 83	186	49	A 106	202	....	....	207	169
C 84	165	41	B 154	191	204	183	207	169
C 85	188	44	226	160	....	....	65	218
C 86	176	44	A 106	202	....	....	207	169
C 87	204	44	B 150	105	A 116	218	207	169
C 88	188	50	226	160	....	....	65	218
C 89	215	49	207	169	....	....	65	218
C 90	215	51	B 154	191	204	183	207	169
C 91	119	35	....	....	....	....	......	....
C 92	197	48	A 88	187	....	....	......	....
C 93	161	45	....	....	....	....	......	....
C 94	175	46	....	....	....	....	......	....
C 96	180	49	207	169	....	....	65	218
C 97	149	33	....	....	....	....	......	....
C 99	179	49	A 96	204	....	....	207	169
C 100	111	39	A 105	200	....	....	207	169
C 101	125	41	A 116	218	65	218	207	169
C 102	111	37	A 105	200	....	....	207	169
C 103	193	46	A 111	204	....	....	65	218
C 104	174	43	....	....	....	....	......	....
C 105	188	48	....	....	....	....	......	....
C 106	189	48	A 106	202	....	....	207	169
C 107	133	46	A 105	200	....	....	207	169
C 108	193	50	B 151	136	A 116	218	207	169
C 110	177	50	....	....	....	....	......	....
C 111	178	50	A 106	202	....	....	207	169
C 112	219	53	B 154	191	204	183	207	169
①......	177.43	45.22		181.37		202.44		185.96
②......	180.97							

① Average of yard. ② Unidentified eggs added.

concerned, under the same conditions as those of subsequent years. The average of the annual individual records of this yard was 117.64 a hen, or including eggs laid outside of nest, 120.68.

Third Generation. Table III gives record for yard 15, pullets of the second generation from the original flock. These pullets were not pedigreed; that is, the egg record of dam and sire's dam is not known except in the case of two hens; but the pullets were taken from the original flock as a whole after one-third of the poorest had been discarded. Of the two hens mentioned, one laid 218 eggs and her dam laid also 218; the other was from a poor layer; laying 45 eggs.

The record of this flock is higher than would be expected from the production of the dams, but the explanation is, no doubt, in the possibility that environmental conditions were specially favorable to high production. The record shows that this was true in some respects at least. They were hatched at a uniform time, and came to laying maturity early in the fall; in this respect their conditions were more favorable than was the case in earlier or later years.

The significance of this record is discussed later in the study of rate of laying or short-period production. The fact, however, that the flock from which yard-15 pullets were produced was a culled flock, approximately one-third of the poor layers having been taken out, is no doubt responsible for some of this increase.

Fourth Generation. The records of the pullet flocks of year 1912-13, Tables IV, V, VI, offer the first results of pedigree work, or the records of pullets of known production pedigree on both dam and sire side. The 38 pullets shown in Table IV were from the six best hens in yard 15, 1910-11, whose records are reported in Table III, and whose sires were two males from dams shown in Tables I and II; namely, 65 and 207, records 218 and 169 respectively. Table IV shows that the 38 pullets varied in production from 268 eggs to 3 eggs, and averaged 178.16 eggs. The average of their dams was 210.94 and of the sire's dam 194.79. It is worthy of note that the highest and lowest records in this yard were made by two full sisters, though probably no great importance can be placed upon the record of the lowest hen, C60, which was 3 eggs. While this hen was in apparently good condition until Oct. 19, 1915, near the end of the third year, when she was marketed, it is not impossible

TABLE VI. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 8, 1912-13, Barred Plymouth Rocks.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr	S.D.	Eggs 1st yr
	1st year	Best 2 months						
C 115	227	52	B 151	136	....	....	207	169
C 116	139	35	A 96	204	....	....	207	169
C 117	186	48	A 79	219	....	....	207	169
C 118	173	49	207	169	....	....	65	218
C 119	241	50	A 96	204	....	....	207	169
C 120	173	41	A 81	203	....	....	207	169
C 121	166	36	A 106	202	....	....	207	169
C 122	183	44	A 79	219	....	....	207	169
C 123	139	42	A 78	213	....	....	207	169
C 124	149	46	A 78	213	....	....	207	169
C 125	158	40	A 79	219	....	....	207	169
C 126	167	43	A 116	218	....	....	207	169
C 127	161	50	A 111	204	....	....	65	218
C 128	196	58	A 77	214	....	....	65	218
C 129	174	47	A 79	219	....	....	207	169
C 130	193	41	A 93	201	....	....	207	169
C 133	207	40	207	169	....	....	65	218
C 134	182	55	A 115	188	....	....	207	169
C 136	191	42	B 150	105	....	....	207	169
C 137	223	48	A 111	204	....	....	65	218
C 140	126	43	226	160	....	....	65	218
C 141	144	45	A 78	213	....	....	207	169
C 143	130	42	204	183	....	....	65	218
C 145	190	51	A 79	219	....	....	207	169
C 146	209	52	A 122	259	....	....	207	169
C 147	177	48	A 79	219	....	....	207	169
C 148	166	36	A 81	203	....	....	207	169
C 150	125	39	A 116	218	....		207	169
C 151	107	27	A 77	214	....	....	65	218
C 152	195	52	207	169	....	....	65	218
C 154	139	42	A 96	204	....	....	207	169
C 156	141	40	A 111	204	....	....	65	218
C 157	189	38	B 150	105	....	....	207	169
①......	171.69	44.30	....	196.76	....	....	....	183.85
②......	174.18							

① Average of yard. ② Unidentified eggs added.

TABLE VII. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard B, 1913-14, Barred Plymouth Rocks.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
D 66	150	32	C 69	232	A 77	214	A 116	218
D 67	151	51	C 33	139	A 111	204	A 78	213
D 68	219	55	Yd. 5-6	......	....	....	....	....
D 69	229	54	A 79	219	....	....	A 122	259
D 70	144	42	C 61	158	A 79	219	65	218
D 71	209	55	C 64	235	A 122	259	A 116	218
D 73	165	43	H 26 N	139	204	183	A 81	203
D 74	244	54	A 77	214	....	....	A 122	259
D 75	201	46	A 77	214	....	....	A 122	259
D 77	208	48	C 64	235	A 122	259	A 116	218
D 78	215	48	A 79	219	....	....	A 122	259
D 79	109	47	226	160	65	218	A 81	203
D 80	98	44	C 58	205	A 77	214	A 116	218
D 83	190	48	C 64	235	A 122	259	A 116	218
D 84	236	53	C 146	209	A 122	259	A 77	214
D 85	161	47	A 105	200	....	....	A 81	203
D 87	243	52	C 32	188	A 78	213	A 116	218
D 88	153	44	B 159	188	207	169	A 77	214
D 89	151	42	C 45	142	A 81	203	A 116	218
D 90	240	54	C 64	235	A 122	259	A 116	218
D 91	147	37	C 149	171	A 78	213	A 116	218
D 92	259	53	C 35	225	A 79	219	65	218
D 93	171	54	C 69	232	A 77	214	A 116	218
D 94	112	42	A 93	201	....	....	A 81	203
D 95	194	48	C 35	225	A 79	219	65	218
D 97	201	51	Yd. 6	......	....	....	....	......
D 98	182	49	C 69	232	A 77	214	A 116	218
D 99	86	35	C 40	151	A 77	214	A 116	218
D 100	213	46	C 44	227	A 111	204	A 78	213
D 101	166	50	C 45	171	A 81	203	A 116	218
D 102	166	33	204	183	....	....	A 77	214
D 103	179	46	226	160	65	218	A 81	203
D 104	183	48	A 79	219	....	....	A 122	259
D 105	167	54	C 46	201	A 77	214	A 116	218
D 106	225	49	C 50	224	A 77	214	A 116	218
D 107	179	43	C 52	157	A 77	214	A 116	218
D 108	187	48	C 41	177	A 79	219	65	218
D 109	130	45	A 106	202	....	....	A 122	259
D 111	176	52	C 37	199	A 79	219	65	218
D 112	160	49	C 58	205	A 77	214	A 116	218
D 113	199	51	A 93	201	....	....	A 81	203
D 115	170	43	B 246	116	226	160	A 77	214
D 116	184	50	B 159	188	207	169	A 77	214
D 117	169	47	204	183	....	....	A 77	214
D 118	233	55	C 64	235	A 122	259	A 116	218
D 119	209	50	C 64	235	A 122	259	A 116	218
D 120	95	41	C 37	199	A 79	219	65	218
D 121	149	43	B 160	119	207	169	A 77	214
D 122	162	37	B 246	116	226	160	A 77	214
D 123	233	52	A 79	219	....	....	A 122	259
D 124	116	37	226	160	65	218	A 81	203
D 126	177	41	Yd. 7	......	....	....	A 111	204
①......	178.75	46.88	....	193.86	....	215.05	....	220.52
②......	185.00							

① Average of yard. ② Unidentified eggs added.

that her low performance was due to some physical condition of the egg-laying organs, not at all related to any inherited capacity to lay.

Table V gives a record of yard 7 containing 37 pullets that made complete one-year records. They averaged 180.97 eggs a hen. Their dams averaged in their first year 181.37 eggs, and their sire's dam 185.96 eggs.

TABLE VIII. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard C, 1913-14, Barred Plymouth Rocks.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
D 128	145	43	A 78	213	....	......	A 122	259
D 129	189	49	C 68	147	A 78	213	A 116	218
D 130	183	48	C 70	152	A 77	214	A 116	218
D 131	173	46	A 78	213	......	......	A 122	259
D 132	158	48	B 142	144	A 116	218	A 77	214
D 133	216	52	A 78	213	....	......	A 122	259
D 134	88	37	C 57	178	A 77	214	A 116	218
D 135	188	47	A 78	213	....	......	A 122	259
D 138	177	57	A 78	213	....	......	A 122	259
D 139	103	53	A 78	213	....	......	A 122	259
D 140	164	40	A 78	213	....	......	A 122	259
D 142	125	37	A 78	213	......	......	A 122	259
D 144	133	49	C 68	147	A 78	213	A 116	218
D 146	117	46	C 146	209	A 122	259	A 77	214
D 147	129	34	C 49	194	A 79	219	65	218
D 149	212	45	Yd. 5-6	......	....	......	....	......
D 150	196	54	C 68	147	A 78	213	A 116	218
D 151	139	39	Yd. 6	......	....	......	....	......
D 154	248	54	Yd. 5-6	......	....	......	....	......
D 155	187	45	A 105	200	....	......	A 81	203
D 156	159	48	A 93	201	....	......	A 81	203
D 157	175	42	C 38	213	A 111	204	A 78	213
D 158	101	47	B 159	188	207	169	A 77	214
D 159	165	50	C 40	151	A 77	214	A 116	218
D 160	159	48	A 111	204	....	......	A 77	214
D 162	203	48	C 35	225	A 79	219	65	218
D 164	151	54	B 158	131	226	160	A 77	214
D 165	193	51	A 78	213	....	......	A 122	259
D 166	217	53	C 41	177	A 79	219	65	218
D 167	142	34	C 61	158	A 79	219	65	218
D 168	163	50	C 125	158	A 79	219	A 77	214
D 169	107	31	C 57	178	A 77	214	A 116	218
D 170	175	42	A 93	201	....	......	A 81	203
D 171	224	50	A 111	204	....	......	A 77	214
D 172	221	56	B 252	96	226	160	A 77	214
D 173	121	30	B 154	191	204	182	A 81	203
D 174	174	46	B 158	131	226	160	A 77	214
D 175	102	43	C 46	201	A 77	214	A 116	218
D 177	268	58	A 83	167	....	......	A 122	259
D 178	188	53	A 106	202	....	......	A 122	259
D 180	239	61	C 125	158	A 79	219	A 77	214
D 182	151	42	A 78	213	....	......	A 122	259
D 183	218	52	Yd. 5	......	....	......	....	......
D 184	122	43	C 49	194	A 79	219	65	218
D 186	160	52	H26N	139	204	182	A 81	203
D 187	130	28	Yd. 6	......	....	......	....	......
D 188	179	46	Yd. 7	......	....	......	A 111	204
D 190	176	42	Yd. 7	......	....	......	A 111	204
D 192	217	54	Yd. 7	......	....	......	A 111	204
D 193	193	57	Yd. 7	......	....	......	A 111	204
D 194	177	39	Yd. 7	......	....	......	A 111	204
①......	169.41	46.57	....	183.32	....	205.75	....	224.57
②......	175.59							

① Average of yard. ② Unidentified eggs added.

Table VI gives a record of 33 pullets in yard 8, 1912-13. Their average production was 174.18. They were late hatched, on the average. Their dams' records averaged 196.76, and sire's dams 183.85.

The average of the 108 Barred Rock pullets in yards 6, 7, 8, in 1912-13 was 177.91.

Fifth Generation. The records of the next generation of Barred Rock pullets are shown in Tables VII and VIII, yards B and C. Fifty-

TABLE IX. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard L, 1914-15, Barred Plymouth Rocks.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
E 578	172	49	C 50	224	A 77	214	A 122	259
E 580	134	40	Yd. B	......	....	......	A 78	213
E 581	143	43	Yd. B	......	....	......	A 78	213
E 582	188	44	C 76	198	B 154	191	H12N	144
E 591	196	48	Yd. B	......	....	......	A 78	213
E 594	222	46	Yd. B	......	....	......	A 78	213
E 595	158	46	C 35	225	A 79	219	C 69	232
E 596	182	42	Yd. B	......	....	......	A 78	213
E 597	200	47	Yd. B	......	....	......	A 78	213
E 599	187	49	Yd. B	......	....	......	A 78	213
E 602	172	43	C 151	167	A 77	214	A 77	214
E 605	199	50	Yd. B	......	....	......	A 78	213
E 609	195	49	Yd. B	......	....	......	A 78	213
E 611	134	31	C 41	177	A 79	219	Yd. 7	......
E 612	204	59	A 96	204	....	......	A 122	259
E 613	175	49	C 62	175	A 78	213	Yd. 7	......
E 617	221	54	C 50	224	A 77	214	A 122	259
E 618	108	39	Yd. B	......	....	......	A 78	213
E 619	185	50	C 117	186	A 79	219	H12N	144
E 621	139	52	C 50	224	A 77	214	A 122	259
E 622	155	38	C 43	142	A 81	203	A 77	214
E 623	218	48	Yd. B	......	....	......	A 78	213
E 624	189	56	C 168	193	B 151	136	Yd. 7	......
E 625	177	44	C 63	140	A 77	214	Yd. 7	......
E 626	201	43	204	183	......	......	Yd. 7	......
E 627	160	40	C 149	171	A 78	213	Yd. 7	......
E 628	218	43	C 63	140	A 77	214	Yd. 7	......
E 629	186	52	C 41	177	A 79	219	Yd. 7	......
E 630	210	47	C 41	177	A 79	219	Yd. 7	......
E 631	160	37	Yd. B	......	....	......	A 78	213
E 633	114	33	204	183	....	......	Yd. 7	......
E 634	175	41	204	183	....	......	Yd. 7	......
2288	143	42	C 62	175	A 78	213	Yd. 7	......
①	176.36	45.27	....	181.33	....	208.71	....	216.19
②	185.78							

① Average of yard. ② Unidentified eggs added.

two pullets, yard B, averaged 185 eggs; the dams averaged 193.86; dams' dams, 215.05; sires' dams, 220.52. Table VIII shows an average production of 175.59 for the 51 pullets in yard C, with dams' average 183.32. Dams' dams 205.75 and sires' dams, 224.57, high record of 268 eggs, equaled the previous high record for Barred Rocks in the previous year, yard 6. In a few cases the dams' record is low, but with dam's dams high and sire's dam high, they are left in the tabulation.

Sixth Generation. The sixth generation of pullets is shown in Tables IX and X, yards L and P. The former averaged 185.78 and the latter 189.01. The average of dams in yard L was 181.33, of dam's dam 208.71, and sire's dam 216.19. In yard P the average of dams is 213.84, dam's dam 214.81, sire's dam 231.68.

Seventh Generation. A shortage of help and interruptions due to war service were responsible for the small number of pullets available for experimentation for the years 1915-16 and 1916-17. For the year 1915-16, no records can be given for comparison. In 1916-17, yard 18, Table XI, averaged 201.9, with dam's average 247.36, dams' dams 197.44, sires' dams 223.13.

TABLE X. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard P, 1914-15, Barred Plymouth Rocks.

Hen No.	Production 1st year	Production Best 2 months	Dam	1st yr. Eggs	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
E 501	157	47	C 152	195	207	169	A 78	213
E 506	139	38	A 78	213	......	......	C 69	232
E 507	173	44	A 78	213	......	......	C 69	232
E 508	165	49	C 166	233	A 96	204	C 69	232
E 509	136	45	C 152	195	207	169	A 78	213
E 511	135	31	C 112	219	B 154	191	C 64	235
E 512	183	47	C 112	219	B 154	191	C 64	235
E 514	193	38	A 78	213	......	......	C 69	232
E 515	245	52	C 56	210	A 111	204	C 64	235
E 516	197	43	A 78	213	......		C 69	232
E 518	152	56	C 166	233	A 96	204	C 69	232
E 519	141	44	C 56	210	A 111	204	C 64	235
E 520	176	45	C 67	187	A 111	204	C 64	235
E 521	246	48	C 146	209	A 122	259	C 69	232
E 523	179	40	C 90	215	B 154	191	C 69	232
E 525	226	54	C 166	233	A 96	204	C 69	232
E 526	140	42	A 77	214	......	......	C 64	235
E 527	155	41	C 146	209	A 122	259	C 69	232
E 529	156	40	A 77	214	......	......	C 64	235
E 531	231	57	C 146	209	A 122	259	C 69	232
E 532	198	48	C 146	209	A 122	259	C 69	232
E 534	222	54	C 146	209	A 122	259	C 69	232
E 535	195	46	C 146	209	A 122	259	C 69	232
E 536	209	51	A 77	214	......	......	C 64	235
E 538	150	42	C 112	219	B 154	191	C 64	235
E 539	182	45	A 78	213	......	......	C 69	232
E 542	238	58	C 146	209	A 122	259	C 69	232
E 543	243	52	C 146	209	A 122	259	C 69	232
E 544	133	45	A 77	214	......	......	C 64	235
E 545	244	49	C 90	215	B 154	191	C 69	232
E 546	218	52	A 78	213	......	......	C 69	232
E 548	173	47	A 77	214	......	......	C 64	235
E 549	176	48	C 56	210	A 111	204	C 64	235
E 550	137	41	C 112	219	B 154	191	C 64	235
E 555	143	41	C 56	210	A 111	204	C 64	235
E 556	153	41	C 56	210	A 111	204	C 64	235
E 557	234	57	C 166	233	A 96	204	C 69	232
E 558	221	56	C 119	241	A 96	204	A 78	213
①	184.06	46.69	....	213.84	....	214.81	....	231.68
②	189.01							

① Average of yard. ② Unidentified eggs added.

TABLE XI. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 18, 1916-17, Barred Plymouth Rocks.

Hen No.	Production 1st year	Production Best 2 months	Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
G 1	199	52	D 177	268	A 83	167	C 50	224
G 2	203	49	D 92	259	C 35	225	C 50	224
G 3	195	58	E 561	185	......	......	C 50	224
G 4	183	53	E 561	185	....	......	C 50	224
G 5	214	44	D 177	268	A 83	167	C 50	224
G 7	220	50	D 92	259	C 35	225	C 50	224
G 8	195	57	D 92	259	C 35	225	C 50	224
G 9	212	55	D 177	268	A 83	167	C 50	224
G 10	179	48	D 92	259	C 35	225	C 50	224
G 11	185	45	E 543	243	C 146	209	D 52	214
G 12	154	52	D 177	268	A 83	167	C 50	224
①	194.45	51.18	....	247.36	....	197.44	....	223.13
②	201.90							

TABLE XII. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard E, 1917-18, Barred Plymouth Rocks.

Hen No.	Production		Dam	Eggs 1st yr.	D.D	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
H 101	201	46	G 7	220	D 92	259	D 52	214
H 102	140	41	Yd. M	......	......	......	D 87	243
H 103	239	51	F 83	179	C 56	210	E 543	243
H 104	205	44	G 1	199	D 177	268	D 52	214
H 105	204	50	G 7	220	D 92	259	D 52	214
H 106	227	49	F 90	209	D 154	248	E 543	243
H 107	211	45	G 1	199	D 177	268	D 52	214
H 108	158	44	F 84	169	D 156	159	E 543	243
H 109	133	43	G 10	179	D 92	259	D 52	214
H 111	214	52	G 3	195	E 561	185	D 52	214
H 112	204	41	G 11	185	E 543	243	D 52	214
H 113	182	47	F 90	209	D 154	248	E 543	243
H 114	206	54	Yd. M	......	......	......	D 87	243
H 115	74	31	D 18	271	A 96	204	D 177	268
H 116	208	48	Yd. M	......	......	......	D 87	243
H 118	94	28	Yd. M	......	......	......	D 87	243
H 119	181	46	Yd. N	......	......	......	D 177	268
H 120	211	44	Yd. N	......	......	......	D 177	268
H 121	185	45	Yd L	......	......	......	D 39	270
H 122	240	48	F 4	192	D 100	213	E 543	243
H 123	189	54	Yd. L	......	......	......	D 39	270
H 124	207	53	Yd. M	......	......	......	D 87	243
H 125	113	33	Yd. M	......	......	......	D 87	243
H 126	184	52	Yd. M	......	......	......	D 87	243
H 127	162	44	G 166	243	D 136	223	D 87	243
H 128	217	46	Yd. N	......	......	......	D 177	268
H 129	54	27	Yd. N	......	......	......	D 177	268
H 130	251	52	Yd. N	......	......	......	D 177	268
H 131	191	50	Yd. N	......	......	......	D 177	268
H 132	242	47	F 9	161	C 112	219	D 84	236
H 133	277	57	Yd. N	......	......	......	D 177	268
H 134	269	58	Yd. N	......	......	......	D 177	268
H 135	91	32	Yd. N	......	......	......	D 177	268
H 136	219	41	F 4	192	D 100	213	E 543	243
H 137	224	44	F 89	182	D 136	223	E 543	243
H 138	234	49	Yd. N	......	......	......	D 177	268
H 139	158	46	Yd. M	......	......	......	D 87	243
H 140	210	42	Yd. M	......	......	......	D 87	243
H 141	135	35	Yd. M	......	......	......	D 87	243
H 142	268	53	Yd. N	......	......	......	D 177	268
H 144	210	51	Yd. 0	......	......	......	E 561	185
H 145	270	56	Yd. N	......	......	......	D 177	268
H 146	232	54	Yd. 0	......	......	......	E 561	185
H 147	200	47	Yd. N	......	......	......	D 177	268
H 148	191	50	Yd. 0	......	......	......	E 561	185
H 150	183	45	Yd. 0	......	......	......	E 561	185
H 151	153	44	Yd. 0	......	......	......	E 561	185
H 153	224	52	Yd. N	......	......	......	D 177	268
H 154	251	53	Yd. N	......	......	......	D 177	268
H 155	244	54	Yd. N	......	......	......	D 177	268
H 156	226	53	Yd. N	......	......	......	D 177	268
H 157	225	50	Yd. 0	......	......	......	E 561	185
H 159	220	50	Yd. N	......	......	......	D 177	268
H 160	216	46	Yd. N	......	......	......	D 177	268
H 161	211	47	Yd. 0	......	......	......	E 561	185
H 162	308	60	Yd. N	......	......	......	D 177	268
H 163	215	49	Yd. M	......	......	......	D 87	243
H 165	229	52	Yd. L	......	......	......	D 39	270
H 166	282	54	Yd. L	......	......	......	D 39	270
H 167	244	54	Yd. L	......	......	......	D 39	270
H 168	200	47	Yd. L	......	......	......	D 39	270
H 169	203	46	Yd. L	......	......	......	D 39	270
①	202.40	47.19	......	200.23	......	229.47	....	244.58
②	214.63							

① Average of yard. ② Unidentified eggs added.

Eighth Generation. In the eighth generation, Table XII, there are 62 pullets in yard E with average records of 214.63 eggs. This shows a rather remarkable increase over previous year, possibly more than would reasonably be expected in one generation as an average. Environmental conditions were more favorable than in some of the previous years. The dams averaged 200.23, dams' dams 229.47, sires' dams 244.58. In several cases the dam's record is not known, only the yard in which the dam was bred. In those cases, however, the record of the dam was high, for all the hens in the yard were of good records.

Effect of Close Confinement. To determine how much of a factor methods of housing and yarding are in our breeding experiments, a pen of twenty Barred Plymouth Rock pullets from our experimental flock were confined throughout the year, 1915-16, in a house 8 by 12 feet in size. It was the same style of house in which our experimental flocks were kept, but the experimental flocks had the liberty of outdoor yards at all seasons. This pen averaged 182.6 eggs a year with high record of 289 and low of 85. There were no deaths during the year. This record is practically the same as for the experimental flocks of the same breeding, and indicates that conditions as to housing and yarding are not important factors, so far as indoor and outdoor management are concerned.

Fig. 2. A pen of the Oregon Station's strain of Barred Plymouth Rocks. This pen tied for second place with a pen of the Station's "Oregons" in the egg-laying contest at the Panama-Pacific International Exposition, San Francisco. The Station sent three pens and won the first three prizes.

It is understood, of course, that this test and these conclusions have nothing to do with the question of management as it affects breeding stock or reproduction. Because of radical difference in environment, the record of this pen is not included in tabulation in comparing the effect of breeding.

RESULTS WITH WHITE LEGHORNS

Foundation Stock. The production of the original stock of White Leghorns is given in Table XIII. These pullets were bought from different breeders in Oregon, and fifty were used as foundation stock. The production records for the term of the experiment embraced 386 pullets.

In the first year, the average production was 106.88 eggs a hen. The highest record was 183 and the lowest 2 eggs.

Second Generation. In the second year (Table XIV) there were only 21 pullets with records, the highest being 229 eggs and the lowest 3, average 104.67 eggs. In this case, no "floor" eggs are counted, there being no record of unidentified eggs. Were these eggs accounted for the record of these pullets would doubtless have equalled the record of the previous year. These pullets were not pedigreed birds but produced promiscuously from the original flock and from males of unknown ancestry. Some of these pullets were later used for breeding. Hen O34 was our first 200-egg Leghorn, and was the foundation of our high-producing Leghorn stock.

Fig. 3. Pen 3 of White Leghorns, 1914-15; record 230.12. See Table XVII.

Third Generation. In the third year, 1910-11 (Table XV), there are only 10 pullets available. These were not pedigreed, but hatched from the foundation stock after the poor layers had been culled out. They averaged 164.10 eggs with highest 240 and lowest 98, hen A27 making a record of 240. This hen lived until she was 8 years and one month old, and in that time had laid in trap-nests, 1188 eggs. All of the present Station Leghorns trace pedigrees back to this hen.

Fourth Generation. Table XVI gives the record of fourteen White Leghorn pullets included in yard 9 of Oregons, 1912-13. They averaged 208.93 eggs with dam's average 223.85 and sire's dam 229. Three of these birds it will be noticed were from an inbred mating of dam to cockerel. Their numbers are C526, C551, and C584.

Fifth Generation. In 1914-15 (Table XVII) sixteen pedigreed pullets in yard 3 averaged 230.12 eggs, with dams' record of 242.19, dams' dams 222.33, and sires' dams 233.13. The highest record was 302 and the lowest 148. This yard produced our first 300-egg Leghorn. In the

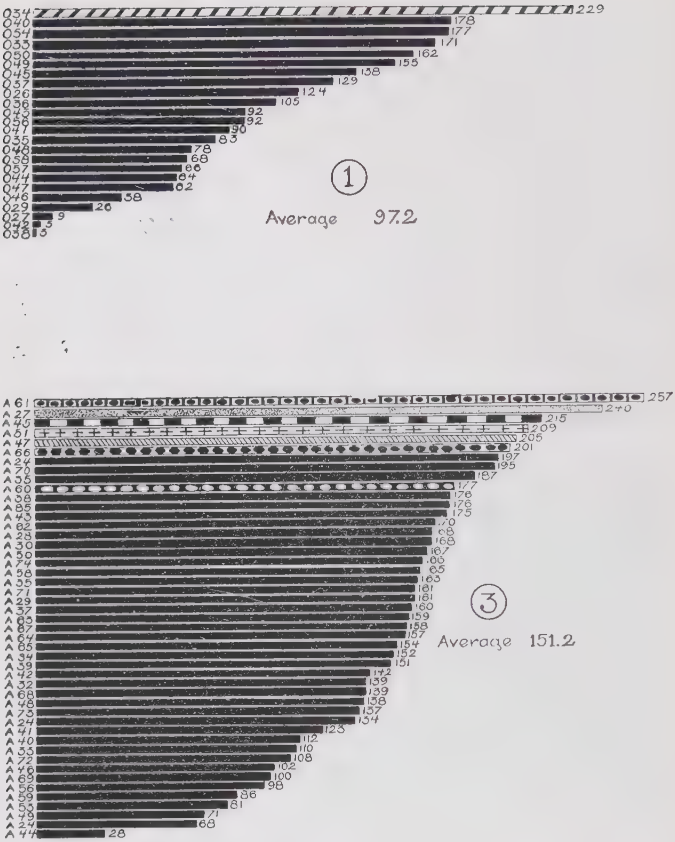


Fig. 5. These charts show graphically a progressive increase in production by selecting the best layers in the flock for breeding. Chart 1 is the record of an unselected pen of White Leghorns; Chart 2, an unselected pen of crosses; Chart 3, a partly selected pen of White Leghorns and crosses; and Chart 4 a pen bred from high producers or pedigreed stock. Chart 4 is the result of breeding from the best hens represented in Charts 1, 2, and 3, all better than 200-egg hens except one, and this one laid 234 in second year. Full sisters in Chart 4 are represented by lines of similar pattern. A son of O34, Chart 1, was the sire of all the pullets except daughters of 250, this hen being inbred to her son. There are also three daughters of O34 inbred to son. Fewer poor layers and more good layers are shown in Chart 4 than in the flocks from which their parents were selected, but the increased production has not been followed by uniformity in production. The average production of the daughters does not equal the production of the parents, but there are individual pullet records higher as well as lower than the production of the parents.

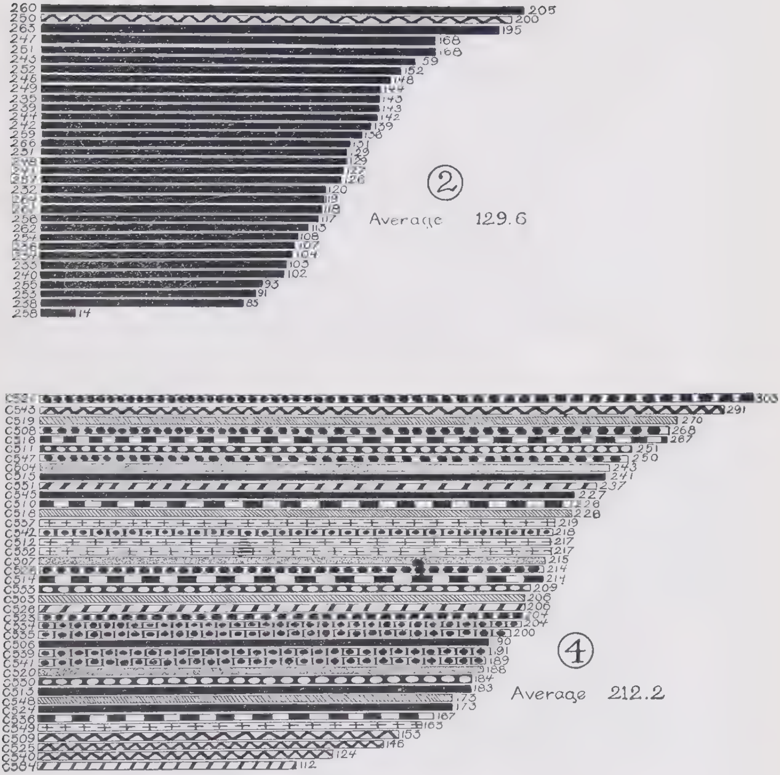


Fig. 5. These charts show graphically a progressive increase in production by selecting the best layers in the flock for breeding. Chart 1 is the record of an unselected pen of White Leghorns; Chart 2, an unselected pen of crosses; Chart 3, a partly selected pen of White Leghorns and crosses; and Chart 4 a pen bred from high producers or pedigreed stock. Chart 4 is the result of breeding from the best hens represented in Charts 1, 2, and 3, all better than 200-egg hens except one, and this one laid 234 in second year. Full sisters in Chart 4 are represented by lines of similar pattern. A son of O34, Chart 1, was the sire of all the pullets except daughters of 250, this hen being inbred to her son. There are also three daughters of O34 inbred to son. Fewer poor layers and more good layers are shown in Chart 4 than in the flocks from which their parents were selected, but the increased production has not been followed by uniformity in production. The average production of the daughters does not equal the production of the parents, but there are individual pullet records higher as well as lower than the production of the parents.

same year 42 pullets in yard O (Table XVIII) averaged 216.72 with dams' record 236.97, dams' dams 221.68, sires' dams 237.25.

Sixth Generation. In 1916-17, yard P (Table XIX), 49 pullets average 188.96 with dams' record at 209.74, dams' dams 247.27, sires' dams 251.71 eggs. The large proportion of these pullets were early hatched, and some of them went through the moult in the fall, which doubtless reduced the production.

In yard Q (Table XX) the same year 57 pullets averaged 172.65, dams 211.75, dams' dams 241.56, sires' dams 258.74. This yard was not under favorable conditions for high record. There was not much uniformity in the ages; some were early hatched and moulted, and others were late and did not start to lay early enough to make a good record. In the same year 11 pullets of yard 15 (Table XXI) averaged 225.27, with dams 227.64, dams' dams 245.09, and sires' dams 242.18. These 11 pullets were of practically the same production pedigree as P and Q. The fact that they did not moult probably explains their high record.

Fig. 5. A pen of the Oregon Station's pedigreed strain of White Leghorns. This pen won first place in a year's egg-laying contest at the Panama-Pacific International Exposition, San Francisco.

Seventh Generation. In 1917-18, sixty pullets in yard F (Table XXII) averaged 222.22 eggs, with high records of 300 and low of 23. Unfortunately there is only a yard pedigree for the dam for most of these hens. Yard R was made up of high-producing stock that averaged 214.14 eggs. The 19 hens with individual pedigrees had dams of averages of 235.42 eggs. The sire's dam, however, in all cases was from our highest record Leghorn, E248, 302 eggs in first year. See Table XVII. The production of yard F would, no doubt, have been higher but for an accident or oversight in May when the fowls had no water for two days. This caused a reduction from about sixty percent to

TABLE XIII. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yards 4 and 5, 1908-9, White Leghorns.

Hen No.	Production 1st year	Production Best 2 months	Hen No.	Production 1st year	Production Best 2 months	Hen No.	Production 1st year	Production Best 2 months
1	177	50	26	112	37	43	97	27
2	83	34	27	150	40	45	119	33
4	38	13	28	14	5	46	111	35
5	127	38	29	72	25	49	24	12
6	87	26	30	116	28	50	104	33
8	170	42	31	90	29	51	48	17
9	95	33	32	136	49	52	164	41
10	140	42	33	119	33	54	91	28
11	146	42	34	65	22	55	15	13
13	114	35	35	166	43	56	169	45
15	139	44	36	87	36	58	74	37
18	143	40	37	66	30	59	158	41
19	107	37	38	155	38	60	132	34
21	154	38	39	128	40	61	71	35
22	76	29	40	183	45	62	34	14
23	110	33	41	2	2	64	96	36
25	131	42	42	122	35			
Average of yard							106.14	32.54
Unidentified eggs added							106.88	

TABLE XIV. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 9, 1909-10, White Leghorns.

Hen No.	Production 1st year	Production Best 2 months	Hen No.	Production 1st year	Production Best 2 months	Hen No.	Production 1st year	Production Best 2 months
O 33	171	42	O 41	90	40	O 48	78	31
O 34	229	47	O 42	5	2	O 49	155	36
O 35	83	23	O 43	92	22	O 50	162	38
O 36	105	41	O 44	64	34	O 54	178	44
O 37	129	29	O 45	150	37	O 56	92	31
O 38	3	2	O 46	38	19	O 57	66	33
O 40	178	48	O 47	62	22	O 58	68	24
Average of yard							104.67	30.71

TABLE XV. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 1, 1910-11, White Leghorns.

Hen No.	Production 1st year	Production Best 2 months	Hen No.	Production 1st year	Production Best 2 months	Hen No.	Production 1st year	Production Best 2 months
A 27	240	51	A 45	215	47	A 56	98	34
A 38	176	47	A 50	167	42	A 67	158	42
A 41	123	26	A 51	209	48	A 69	118	38
A 42	142	38						
Average of yard							164.6	41.3

TABLE XVI. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 9, 1912-13, White Leghorns.

Hen No.	Production 1st year	Production Best 2 months	Dam	Eggs 1st year	D.D.	Eggs 1st yr.	S.D.	Eggs 1st year
C 504	243	51	A 27	240	--------	--------	O 34	229
C 507	215	53	A 27	240	--------	--------	O 34	229
C 510	226	47	A 45	215	--------	--------	O 34	229
C 514	214	52	A 45	215	--------	--------	O 34	229
C 515	241	53	A 27	240	--------	--------	O 34	229
C 516	267	54	A 45	215	--------	--------	O 34	229
C 520	188	47	A 27	240	--------	--------	O 34	229
C 526	206	47	O 34	229	--------	--------	O 34	229
C 536	167	44	A 45	215	--------	--------	O 34	229
C 537	219	48	A 51	209	--------	--------	O 34	229
C 549	163	36	A 51	209	--------	--------	O 34	229
C 551	225	51	O 34	229	--------	--------	O 34	229
C 552	217	44	A 51	209	--------	--------	O 34	229
C 584	119	40	O 34	229	--------	--------	O 34	229
①	207.85	47.64	......	223.85	--------	--------	......	229.00
②	208.93							

① Average of yard. ② Unidentified eggs added.

TABLE XVII. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 3, 1914-15, White Leghorns.

Hen No.	Production 1st year	Production Best 2 months	Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
E 247	271	57	C 516	267	A 45	215	A 27	240
E 248	302	58	C 516	267	A 45	215	A 27	240
E 249	209	49	A 27	240	....	......	O 34	229
E 250	213	48	C 504	243	A 27	240	O 34	229
E 251	237	50	A 27	240	....	......	O 34	229
E 252	229	53	O 34	229	....	....	A 27	240
E 253	233	52	A 27	240	....	......	O 34	229
E 254	205	50	C 515	241	A 27	240	O 34	229
E 255	276	60	C 516	267	A 45	215	A 27	240
E 256	195	50	A 27	240	....	......	O 34	229
E 257	212	47	C 504	243	A 27	240	O 34	229
E 258	234	47	O 34	229	....	......	A 27	240
E 259	189	50	C 496	195	B 228	167	O 34	229
E 260	249	52	A 27	240	....	......	O 34	229
E 261	230	49	B 12	251	O 34	229	A 27	240
E 262	148	47	C 504	243	A 27	240	O 34	229
①	227.00	51.19	......	242.19	...	222.33	....	233.13
②	230.12							

① Average of yard. ② Unidentified eggs added.

forty percent in a few days, and it was a week or more before they got back to former production.

In the same year, yard G (Table XXIII), 56 pullets averaged 201.85, and their dams averaged 234.5, dams' dams 247.95, sires' dams 236.81. Highest record 298, lowest, 56. These pullets were later-hatched and did not come to laying at as favorable a date as yard F. Had the conditions been favorable, the production of this yard would, no doubt, have been higher.

As it is, the increase in production in the seven generations of White Leghorns was 105.51, the production of the last year lacking just one egg of being double the production of the first generation or foundation stock.

TABLE XVIII. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard O, 1914-15, White Leghorns.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr
	1st year	Best 2 months						
E 1	270	51	C 516	267	A 45	215	A 27	240
E 2	219	52	Yd. F	*	....	......	A 27	240
E 3	248	54	A 27	240	....	......	O 34	229
E 5	230	52	C 516	267	A 45	215	A 27	240
E 6	177	50	C 551	214	O 34	229	A 27	240
E 7	270	54	B 12	251	O 34	229	A 27	240
E 8	215	49	C 516	267	A 45	215	A 27	240
E 9	259	51	B 12	251	O 34	229	A 27	240
E 12	244	49	Yd. F	*	....	......	A 27	240
E 13	258	48	B 12	251	O 34	229	A 27	240
E 14	247	56	C 516	267	A 45	215	A 27	240
E 15	232	50	C 504	243	A 27	240	O 34	229
E 16	203	49	Yd. F	*	....	......	A 27	240
E 17	211	43	Yd. F	*	....	......	A 27	240
E 18	229	43	A 27	240	....	......	O 34	229
E 19	235	50	B 12	251	O 34	229	A 27	240
E 20	243	47	C 516	267	A 45	215	A 27	240
E 21	259	48	B 12	251	O 34	229	A 27	240
E 24	182	47	Yd. F	*	....	......	A 27	240
E 25	211	50	B 12	251	O 34	229	A 27	240
E 26	219	44	C 504	243	A 27	240	O 34	229
E 27	199	52	B 12	251	O 34	229	A 27	240
E 28	184	45	Yd. F	*	....	......	A 27	240
E 29	253	55	Yd. F	*	....	......	A 27	240
E 30	108	43	C 464	175	B 228	167	O 34	229
E 32	185	50	C 516	267	A 45	215	A 27	240
E 33	270	56	C 504	243	A 27	240	O 34	229
E 34	198	52	C 515	241	A 27	240	O 34	229
E 35	100	35	C 516	267	A 45	215	A 27	240
E 36	164	46	D 718	254	C 515	241	....	......
E 37	217	54	D 399	144	B 9	180	....	......
E 38	128	44	D 327	162	B 3	224	....	......
E 40	245	48	B 12	251	O 34	229	A 27	240
E 41	163	47	D 327	162	B 3	224	....	......
E 42	239	54	A 27	240	....	......	O 34	229
E 43	249	51	D 718	254	C 515	241	....	......
E 44	229	51	B 12	251	O 34	229	A 27	240
E 46	169	49	A 51	209	....	......	A 27	240
E 47	156	46	C 516	267	A 45	215	A 27	240
E 49	219	49	C 464	175	B 228	167	O 34	229
E 50	248	52	C 516	267	A 45	215	A 27	240
E 53	156	42	D 731	193	C 504	243	....	......
①	212.86	49.24	....	236.97	....	221.68	....	237.25
②	216.72							

① Average of yard. ② Unidentified eggs added.
* Pen of high producing birds laying from 101 to 276.

TABLE XIX. ANNUAL AND BEST TWO-MONTHS PRODUCTION

Yard P, 1916-17, White Leghorns.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
G 620	179	36	E 253	233	A 27	240	D 343	220
G 621	255	48	F 595	73(D)	D 718	254	A 27	240
G 622	155	51	E 253	233	A 27	240	D 343	220
G 623	239	50	F 592	211(D)	D 718	254	A 27	240
G 624	183	48	E 257	212	C 504	243	D 343	220
G 626	177	45	E 257	212	C 504	243	D 343	220
G 627	146	51	F 594	176	D 718	254	A 27	240
G 628	191	49	F 594	176	D 718	254	A 27	240
G 630	202	46	E 253	233	A 27	240	D 343	220
G 631	183	50	F 622	248	Yd. 0	------	A 27	240
G 632	222	52	E 254	205	C 515	241	D 343	220
G 633	167	48	F 643	208(D)	D 240	245	A 27	240
G 634	158	50	Yd. 15	*	--------	------	O 34	229
G 635	197	55	F 631	197	Yd. 0	------	A 27	240
G 637	160	41	Yd. 15	*	--------	------	O 34	229
G 638	208	40	Yd. 15	*	--------	------	O 34	229
G 639	225	47	Yd. 15	*	--------	------	O 34	229
G 640	211	48	Yd. K	**	--------	------	A 27	240
G 641	209	49	Yd. I	†	--------	------	A 27	240
G 642	176	41	Yd. 15	*	--------	------	O 34	229
G 643	220	54	Yd. K	**	--------	------	A 27	240
G 644	243	53	Yd. 16	‡	--------	------	C 515	241
G 646	172	48	Yd. K	**	--------	------	A 27	240
G 648	129	41	Yd. K	**	--------	------	A 27	240
G 652	184	44	E 255	276	C 516	267	D 343	220
G 658	165	44	Yd. I	†	--------	------	A 27	240
G 659	197	52	Yd. I	†	--------	------	A 27	240
G 661	197	47	Yd. I	†	--------	------	A 27	240
G 662	184	48	Yd. K	**	--------	------	A 27	240
G 663	197	46	H7ON	161	A 27	240	E 248	302
G 664	185	50	H7ON	161	A 27	240	E 248	302
G 666	132	42	E 255	276	C 516	267	D 343	220
G 667	234	47	E 260	249	A 27	240	D 343	220
G 668	264	51	A 27	240	--------	------	E 248	302
G 671	139	49	H15P	147	A 27	240	E 248	302
G 672	227	52	D 718	254	C 515	241	A 27	240
G 673	163	49	E 220	199	D 718	254	E 248	202
G 674	244	51	A 27	240	--------	------	E 248	302
G 675	156	49	C 590	193	A 27	240	E 248	302
G 676	212	52	C 590	193	A 27	240	E 248	302
G 677	148	47	C 590	193	A 27	240	E 248	302
G 678	129	40	C 590	193	A 27	240	E 248	302
G 679	215	54	H9P	162	A 27	240	E 248	302
G 680	143	40	C 590	193	A 27	240	E 248	302
G 681	137	40	H83N	139	A 27	240	E 248	302
G 682	215	50	E 248	302	C 516	267	D 343	220
G 683	211	51	E 248	302	C 516	267	D 343	220
G 684	127	47	E 248	302	C 516	267	D 343	220
G 685	178	50	H83N	139	A 27	240	E 248	302
①	187.55	47.61	....	209.74	....	247.27	....	251.71
②	188.96							

① Average of yard. ② Unidentified eggs added.

* Pen of high producing birds laying from 173 to 267.

** Pen of high producing birds laying from 106 to 271.

† Pen of high producing birds laying from 167 to 270.

‡ Pen of high producing birds which were at Panama-Pacific Exposition Contest during pullet year and laid from 120 to 204 eggs. Most of these birds laid more in the second year, the highest being 242.

TABLE XX. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard Q, 1916-17, White Leghorns.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
G 720	169	42	F 589	170	C 589	211	A 27	240
G 721	192	49	F 625	228	Yd.0	......	A 27	240
G 722	204	42	E 250	213	C 504	243	D 343	220
G 724	189	47	F 665	205	C 589	211	A 27	240
G 725	231	43	F 655	231	D 268	146	A 27	240
G 726	204	45	F 649	159	C 590	193	A 27	240
G 727	141	39	E 230	199	D 718	254	E 248	302
G 730	188	46	Yd 12	*	--------	------	A 27	240
G 731	204	42	F 750	17	C 590	193	D 718	254
G 732	237	49	Yd I	**	--------	------	A 27	240
G 735	201	47	Yd I	**	--------	------	A 27	240
G 736	207	49	Yd I	**	--------	------	A 27	240
G 738	212	57	Yd K	†	--------	------	A 27	240
G 739	181	42	Yd I	**	--------	------	A 27	240
G 741	114	45	H70N	161	A 27	240	E 248	302
G 742	130	48	H70N	161	A 27	240	E 248	302
G 743	114	36	F 596	209	--------	------	O 34	229
G 744	206	50	F 719	243	E 257	212	C 589	170+
G 745	163	48	F 607	208	--------	------	O 34	229
G 746	144	55	E 230	199	D 718	254	E 248	302
G 747	159	46	E 230	199	D 718	254	E 248	302
G 748	173	48	E 214	135	O 34	229	E 248	302
G 749	196	47	E 255	276	C 516	267	D 343	220
G 750	130	41	E 269	254	Yd.F Leg.	------	E 248	302
G 751	121	35	A 27	240	--------	------	E 248	302
G 752	156	34	E 21	259	B 12	251	A 27	240
G 753	166	51	E 3	248	A 27	240	A 27	240
G 754	103	46	H83N	139	A 27	240	E 248	302
G 755	126	42	H15P	147	A 27	240	E 248	302
G 756	130	46	H83N	139	A 27	240	E 248	302
G 757	127	37	H15P	147	A 27	240	E 248	302
G 758	190	50	E 255	276	C 516	267	D 343	220
G 760	143	45	F 984	194	--------	------	A 27	240
G 761	174	47	E 255	276	C 516	267	D 343	220
G 762	111	38	H15P	147	A 27	240	E 248	302
G 763	177	49	H9P	162	A 27	240	E 248	302
G 764	196	53	E 13	258	B 12	251	A 27	240
G 765	241	47	E 247	271	C 516	267	D 343	220
G 767	256	51	E 247	271	C 516	267	D 343	220
G 768	187	46	E 260	249	A 27	240	D 343	220
G 769	103	36	E 230	199	D 718	254	E 248	302
G 770	202	58	E 260	249	A 27	240	D 343	220
G 771	67	32	H83N	139	A 27	240	E 248	302
G 772	217	49	D 718	254	C 515	241	A 27	240
G 773	185	45	E 248	302	C 516	267	D 343	220
G 774	186	40	E 248	302	C 516	267	D 343	220
G 775	140	45	A 27	240	------------	------	E 248	302
G 776	219	48	E 247	271	C 516	267	D 343	220
G 777	188	41	E 247	271	C 516	267	D 343	220
G 778	171	44	E 260	249	A 27	240	D 343	220
G 779	63	34	H83N	139	A 27	240	E 248	302
G 781	228	52	A 27	240	--------	------	E 248	302
G 782	167	44	H15P	147	A 27	240	E 248	302
G 783	121	39	H15P	147	A 27	240	E 248	302
G 784	217	46	H83N	139	A 27	240	E 248	302
G 785	219	52	E 248	302	C 516	267	D 343	220
G 786	95	27	H83N	139	A 27	240	E 248	302
①	169.84	44.77	....	211.75	....	241.56	....	258.74
②	172.65							

① Average of yard. ② Unidentified eggs added.

* Pen of high producing birds laying from 130 to 263 eggs.

** Pen of high producing birds laying from 167 to 270 eggs.

† Pen of high producing birds laying from 106 to 271 eggs.

TABLE XXI. ANNUAL AND BEST TWO-MONTHS PRODUCTION

Yard 15, 1916-17, White Leghorns.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
G 501	245	58	E 255	276	C 516	267	D 343	220
G 502	215	52	E 247	271	C 516	267	D 343	220
G 503	234	55	E 248	302	C 516	267	D 343	220
G 506	210	55	E 255	276	C 516	267	D 343	220
G 507	184	47	E 258	234	O 34	229	D 343	220
G 508	228	48	E 9	259	B 12	251	A 27	240
G 509	196	52	F 701	172	C 551	214	A 27	240
G 510	160	42	F 701	172	C 551	214	A 27	240
G 512	238	52	E 3	248	A 27	240	A 27	240
G 513	234	51	H15P	147	A 27	240	E 248	302
G 514	221	56	H15P	147	A 27	240	E 248	302
①	215.00	51.63	....	227.64	......	245.09	....	242.18
②	225.27							

① Average of yard. ② Unidentified eggs added.

TABLE XXII. ANNUAL AND BEST TWO-MONTHS PRODUCTION

Yard F, 1917-18, White Leghorns.

Hen No.	Production 1st year	Production Best 2 months	Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
H 502	234	48	D 343	220	B 2	223	E 248	302
H 503	208	52	Yd. R	......	....	......	E 248	302
H 504	239	45	Yd. R	......	....	......	E 248	302
H 505	195	44	Yd. R	......	....	......	E 248	302
H 507	230	49	Yd. R	......	....	......	E 248	302
H 508	240	51	Yd. R	......	....	......	E 248	302
H 509	167	36	Yd. R	......	....	......	E 248	302
H 510	230	51	Yd. R	......	....	......	E 248	302
H 511	265	54	Yd. R	......	....	......	E 248	302
H 512	243	50	F 607	208	....	......	E 248	302
H 513	248	49	D 343	220	B 2	223	E 248	302
H 514	167	38	Yd. R	......	....	......	E 248	302
H 515	272	57	Yd. R	......	....	......	E 248	302
H 516	183	52	Yd. R	......	....	......	E 248	302
H 517	238	49	Yd. R	......	....	......	E 248	302
H 518	201	49	Yd. R	......	....	......	E 248	302
H 519	238	50	Yd. R	......	....	......	E 248	302
H 521	256	51	Yd. R	......	....	......	E 248	302
H 522	271	50	Yd. R	......	....	......	E 248	302
H 523	241	50	Yd. R	......	....	......	E 248	302
H 524	254	52	Yd. R	......	....	......	E 248	302
H 525	168	48	Yd. R	......	....	......	E 248	302
H 526	217	50	Yd. R	......	....	......	E 248	302
H 527	213	49	Yd. R	......	....	......	E 248	302
H 528	244	47	Yd. R	......	....	......	E 248	302
H 529	217	50	Yd. R	......	....	......	E 248	302
H 530	235	50	Yd. R	......	....	......	E 248	302
H 531	119	37	E 9	259	B 12	251	E 248	302
H 532	240	51	Yd. R	......	....	......	E 248	302
H 533	298	57	Yd. R	......	....	......	E 248	302
H 534	145	44	E 21	259	B 12	251	E 248	302
H 535	218	51	Yd. R	......	....	......	E 248	302
H 536	256	49	Yd. R	......	....	......	E 248	302
H 537	177	44	Yd. R	......	....	......	E 248	302
H 538	200	43	F 906	170	C 516	267	E 248	302
H 539	208	47	Yd. R	......	....	......	E 248	302
H 540	251	59	Yd. R	......	....	......	E 248	302
H 541	163	47	Yd. R	......	....	......	E 248	302
H 542	149	40	Yd. R	......	....	......	E 248	302
H 543	247	53	Yd. R	......	....	......	E 248	302
H 544	279	51	E 9	259	B 12	251	E 248	302
H 545	300	59	Yd. R	......	....	......	E 248	302
H 548	239	50	Yd. R	......	....	......	E 248	302
H 549	204	42	Yd. R	......	....	......	E 248	302
H 550	178	43	Yd. R	......	....	......	E 248	302
H 551	252	51	E 21	259	B 12	251	E 248	302
H 552	190	44	Yd. R	......	....	......	E 248	302
H 553	227	50	F 609	235	A 27	240	E 248	302
H 555	154	49	Yd. R	......	....	......	E 248	302
H 556	23	9	Yd. R	......	....	......	E 248	302
H 557	265	50	D 343	220	B 2	225	E 248	302
H 558	234	47	E 21	259	B 12	251	E 248	302
H 559	260	48	D 343	220	B 2	223	E 248	302
H 560	246	49	D 343	220	B 2	223	E 248	302
H 561	191	43	D 343	220	B 2	223	E 248	302
H 562	237	49	E 21	259	B 12	251	E 248	302
H 563	187	47	E 9	259	B 12	251	E 248	302
H 564	243	49	E 21	259	B 12	251	E 248	302
H 565	175	46	D 343	220	B 2	223	E 248	302
H 566	224	48	E 3	248	A 27	240	E 248	302
①	218.21	47.78	....	235.42	....	239.78	....	302.00
②	222.22							

① Average of yard. ② Unidentified eggs added.

TABLE XXIII. ANNUAL AND BEST TWO-MONTHS PRODUCTION

Yard G, 1917-18, White Leghorns.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
H 601	249	53	A 27	240	....	......	E248	302
H 605	184	45	Yd. P	......	....	......	A 27	240
H 607	173	53	Yd. P	......	....	......	A 27	240
H 610	222	46	....	......	....	......	....	......
H 612	211	55	G 501	245	E 255	276	C590	193
H 613	226	52	Yd. Q	......	....	......	A 27	240
H 614	173	41	Yd 15	......	....	......	C590	193
H 616	236	47	Yd. Q	......	....	......	A 27	240
H 619	211	49	Yd. P	......	....	......	A 27	240
H 620	223	55	Yd. 8	......	....	......	B 14	215
H 621	219	56	Yd. Q	......	....	......	A 27	240
H 622	117	37	Yd. V1	......	....	......	E230	199
H 623	221	51	Yd. P	......	....	......	A 27	240
H 624	184	47	Yd. Q	......	....	......	A 27	240
H 626	210	53	Yd. P	......	....	......	A 27	240
H 627	252	52	Yd. Q	......	....	......	A 27	240
H 628	218	49	Yd. U	......	....	......	C189	135
H 629	254	54	Yd. Q	......	....	......	A 27	240
H 631	157	39	Yd. Q	......	....	......	A 27	240
H 632	204	52	....	......	....	......	....	......
H 633	216	50	G 682	215	E 248	302	A 27	240
H 635	154	53	Yd. V1	......	....	......	E230	199
H 636	272	54	Yd. Q	......	....	......	A 27	240
H 637	215	52	G 530	226	H 9P	162	D718	254
H 639	197	49	Yd. Q	......	....	......	A 27	240
H 640	247	50	Yd. Q	......	....	......	A 27	240
H 641	200	50	Yd. Q	......	....	......	A 27	240
H 642	155	54	Yd. 6	......	....	......	A 27	240
H 643	204	50	Yd. V1	......	....	......	E230	199
H 644	168	46	E 249	209	A 27	240	A 27	240
H 645	211	41	Yd. V1	......	....	......	E230	199
H 646	195	54	Yd. V2	......	....	......	C551	214
H 648	217	50	E 248	302	C 516	267	A 27	240
H 649	112	43	A 27	240	....	......	E248	302
H 650	182	52	A 27	240	....	......	E248	302
H 651	137	44	E 248	302	C 516	267	A 27	240
H 652	195	46	F 609	235	A 27	240	E248	302
H 653	267	53	Yd. U	......	....	......	C189	135
H 654	204	44	Yd. U	......	....	......	C189	135
H 655	250	50	Yd. U	......	....	......	C189	135
H 656	199	43	Yd. U	......	....	......	C189	135
H 657	224	47	Yd. U	......	....	......	C189	135
H 658	210	44	E 21	259	B 12	251	E248	302
H 660	212	48	E 21	259	B 12	251	E248	302
H 662	298	59	G 528	272	E 247	271	D718	254
H 663	161	51	D 343	220	B 2	223	E248	302
H 664	181	44	F 596	209	....	......	E248	302
H 665	239	49	D 343	220	B 2	223	E248	302
H 666	172	46	G 529	231	E 260	249	D718	254
H 667	252	53	G 529	231	E 260	249	D718	254
H 668	169	45	E 317	243	A 27	240	E248	302
H 669	156	51	G 529	231	E 260	249	D718	254
H 672	139	42	G 743	114	F 596	209	A 27	240
H 673	183	48	E 317	243	A 27	240	E248	302
H 674	186	46	F 607	208	....	......	E248	302
H 675	56	33	G 503	234	E 248	302	C590	193
①	199.63	48.57	....	234.50	....	247.95	....	236.81
②	201.85							

① Average of yard. ② Unidentified eggs added.

CROSSING AND INHERITANCE

Foundation Stock. In 1908-09 reciprocal crosses were made with White Leghorns and Barred Plymouth Rocks, the same sires being used as were used in producing the White Leghorn pullets of yard 9, and the Barred Rocks of yard 6, of the second year. That is to say, in the original yards 4 and 5 there were both Leghorn pullets and Barred Rock pullets, but in one yard there were Leghorn males, and in the other Barred Rock males. Any difference, therefore, in production of the pullets from these matings whether Leghorns or Barred Rocks or crosses, can not be due to differences in males.

Second Generation. In the second generation or crosses there were two yards of pullets. Yard 7 (Table XXIV) averaged 131.06 and yard 8 (Table XXV) 140.36 eggs. The individual records ranged in yard 7 from 205 to 14 and in yard 8 from 211 to 18. The average of the two yards was 135.49 eggs. The pure-bred Leghorn dams averaged 106.88 and their pure-bred Barred Rock dams 86.14, while their half-sister pure-bred Leghorns averaged 104.67 (see Table XIV), and Barred Rocks 120.68 (see Table II). It will be understood, of course, that the dams of the cross-breds were not the same individuals as the dams of the pure-breds, and it may have happened that the production capacity was not the same in each case. The fact, however, remains that the cross-bred pullets of the first generation were half sisters of the pure-bred Leghorn and Barred Rock pullets, being bred from the same males, and they were from the same stock on the dam's side, but from different hens. The experiment had to do, however, with inheritance in egg laying, and not with relative merits of pure-breds and crosses.

Fig. 6. Representatives of Yard E, Oregons, 1913-14. Table XXVIII.

Third Generation. The first generation of cross-bred pullets were mated back to White Leghorn males, but of unknown production pedigree. The progeny is shown in yard 1 (Table XXVI), thirty-seven pullets with average of 147.16 eggs.

Fourth Generation. In the first generation of pedigreed cross-breds (Table XXVII) referred to hereafter as Oregons, twenty pullets in yard 9 averaged 220.8 eggs, ranging in production from 303 to 123. These were sired by a Leghorn male, whose dam laid 229 eggs, except in three cases where an Oregon male was used on his dam. There were three pullets from this inbred mating, namely C543, C525, C540. If these had been eliminated in the tabulation the record of the yard would have been one-half dozen more eggs a hen. Probably they should have been eliminated as in all of our experiments we sought to avoid inbreeding. The average of the dams in yard 9, was 207.45 eggs and of the sires' dams 224.42.

Fifth Generation. In the second generation of pedigreed Oregons, the records of 49 pullets are given in Table XXVIII, yard E. This yard was produced by mating daughters of cross-bred hen 250, with record of 402 eggs in two years, with a Barred Rock male, whose dam A111 produced 204 eggs in her pullet year. These 49 pullets averaged 220.78 eggs, this average exceeding the record of the dam as well as the sire's dam. The record of dams' dam was 200 the first year and 202 the second year. The high second-year record might indicate that she did not lay her full capacity in the first year. The highest record of yard E was 278 and the lowest 58. The dams of 31 of the pullets averaged 186.45 the first year. In the case of eighteen pullets, the dams are not known, but they were in yard C, as well as the thirteen, with pen pedigrees. Yard C pullets were late hatched, averaging 173.66 the first year, but in the second year averaged 199.09.

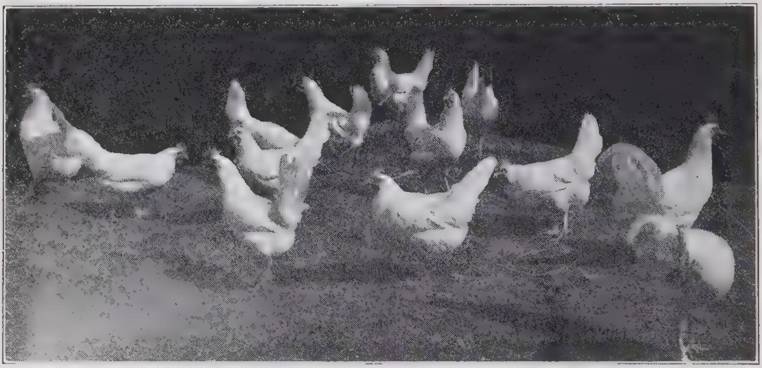


Fig. 7. Pen 4 of Oregons, 1914-15; record 250.2 eggs. All daughters of C521, the first 300-egg hen. See Table XXIX.

Sixth Generation. Yard 4, 1914-15 (Table XXIX) gives the production of ten Oregons that are full sisters; the dam was C521, our first 300-egg hen. The average of the ten pullets was 250.2 eggs, the highest being 283 and the lowest 204, all exceeding 200 eggs. The pedigree showed dam's average 303, dam's dam 201, sires' dam 228.

Another yard of full sisters to pullets in yard 4 is not given in the tabulation on account of the pullets being late or June hatched. The record of the 13 pullets in yard 11, however, was 181.62 eggs, average, with highest 234 and lowest 99.

In Table XXX, the same year, ten pullets in yard 5 averaged 201.70. These pullets were full sisters, with dam's record of 291 eggs, dam's dam 200 eggs, sire's dam 246. In this case there was inbreeding, the dam and sire being from the same dam, but from different sires. The highest record in this yard was 241 eggs and the lowest 152.

In yard 6 (Table XXXI), the same year, were 14 pullets showing a production of 217.27 eggs, the dams averaging 211.43, dams' dams 233.5, sires' dams 286.51.

Yard J (Table XXXII) in the same year, 58 Oregons, laid an average of 219.22 eggs, with high record of 309 and low record at 77. In this case the highest hen should probably be eliminated because she was bred from a low line. Through an oversight the hen was included in the tabulation. Her record and breeding are discussed in another place. If her record were omitted, however, it would make a difference in the average in the yard of less than 1½ eggs a hen.

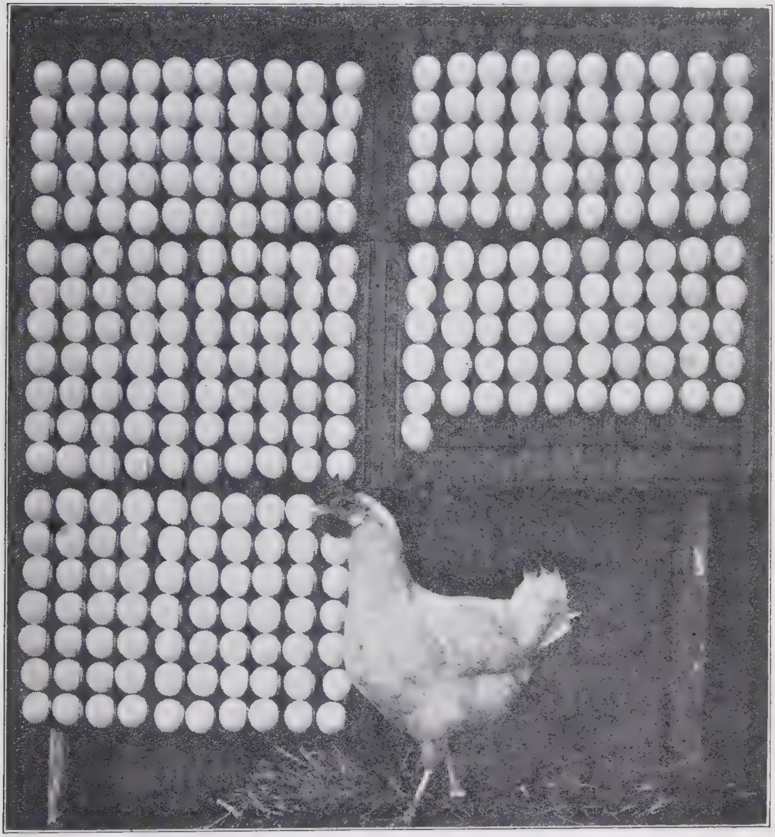


Fig. 8. Oregon hens C543 and number of eggs she laid in first year, 291.

The average of the dams of yard J was 215.24, dams' dams 217.4, sires' dams 214.31. Yard E appearing in the dam's column averaged in the preceding year 220.78, so that the dams of all yard-J pullets averaged over 200 eggs.

Seventh Generation. Only one yard in 1915-16 (shown in Table XXXIII) is available for comparison. The average of the 13 pullets in this yard was 237.77 eggs. The dams are not known in each case, but the sire's dam was C521, record 303; the average of yard M, which was made up of the best hens from yard E (see Table XXVIII) 1913-14 pullets, was 230.42 eggs. The dams' dams' average was also high, and sires' dams' average was 297.46.

To try out the pullets of this breeding under different conditions, a pen of ten was sent to the International Egg-laying Contest at the Storrs Agricultural College, Connecticut; the pen made a record of 212.2 eggs a hen. Another pen of five pullets of the same breeding was sent to the Missouri laying contest and they made a record of 232 eggs a hen. Yard 10 and the two contest pens were all of the same hatch, and of the same pedigree. After yard 10 and the two contest pens were selected, there remained of the flock of pullets 25 which were thought to be the poorest of the flock, judging from external points. It was decided to put these under test under decidedly different conditions; namely, on the writer's backyard lot, where they were kept for the full year in a house 10 by 14 feet in size, and never out of doors. These were cared for by a school boy of 13 years of age, but they got good care. They averaged 216 eggs in the year. The records of these four different pens would indicate that the breeding was responsible for their high production; also that a hen of good laying capacity will respond well to a wide variation in conditions, whether it be feeding, housing, or climate.

Fig. 9. A pen of ten Oregons, winners in International Egg-laying Contest at the Connecticut Agricultural College, 1917-18, record 235.2 eggs a hen. All from pedigreed high producers. This is the highest pen record made there in seven annual contests, representing 700 different pens.

Eighth Generation. In 1917-18, pen 7 (Table XXXIV) containing twelve Oregon pullets averaged 246.91 eggs, with dams' average of 250.92, dams' dams 261.14, sires' dams 287.75. In the same year a pen of ten pullets of practically the same breeding won the egg-laying contest at the Storrs College, with a record of 235.2 eggs, the highest record made at that contest in seven years with ten hens, 100 pens each year.

Sixty-three pullets in yard H, 1917-18 (Table XXXV) averaged 228.57, dams' average 237.79. Dams' dams 269.44, sires' dams 269.62. Highest record 304, lowest 123.

Effect of Close Confinement. In the year 1914-15 another pen of pullets was used which were kept under continuous confinement throughout the year, and for that reason are not included in the tabulation on inheritance. The environmental conditions were entirely different. The purpose was to observe the behavior of the strain under close confinement.

There were 25 pullets in this pen, and they were kept in the same style of house as all the other pens in our breeding experiments; namely, an open-front colony house 8 by 12 feet in dimensions. They were fed the same and were of the same breeding as yard J. They were never outside of the house during the year. One of the pullets died during the year after laying 153 eggs. The remaining twenty-four averaged 228.58. The range was from 299 eggs to 147. All but four of the pullets laid over 200 eggs. They exceeded the production of yard J by about ten eggs a hen. In this pen as in yard J the highest hen was sired by low-line male D461-2. The mortality in J was 6, or 1 in 11.5, while in "shut-in" house, it was 1 in 25.

Under radically different environment this pen shows a considerable increase in production over pen J, indicating (1) that the hen is not particularly sensitive to conditions of housing, providing other factors are favorable, including abundant fresh air and exercise; (2) that the conditions under which our experimental flocks were kept, were not unduly favorable, nor responsible for the increased flock production; (3) that a hen of good laying capacity will lay well under various conditions of housing and yarding.

TABLE XXIV. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 7, 1909-10, Oregons.

Hen No.	Production		Hen No.	Production		Hen No.	Production	
	1st year	Best 2 months		1st year	Best 2 months		1st year	Best 2 months
231	129	34	243	159	35	255	93	29
232	120	32	244	142	32	256	117	37
233	104	26	245	148	32	257	126	34
234	104	32	247	168	35	258	14	5
235	143	36	248	129	32	259	136	32
236	116	31	249	144	38	260	205	45
238	85	29	250	200	40	261	118	27
239	143	34	251	168	39	262	113	27
240	102	27	252	152	33	263	195	41
241	127	34	253	91	30	264	119	33
242	139	29	254	108	24	266	131	35
Average of yard							129.94	32.09
Unidentified eggs added							131.06	....

TABLE XXV. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 8, 1909-10, Oregons.

Hen No.	Production		Hen No.	Production		Hen No.	Production	
	1st year	Best 2 months		1st year	Best 2 months		1st year	Best 2 months
267	139	31	278	98	26	292	133	30
268	174	45	281	130	29	293	169	45
269	101	33	282	117	25	294	130	32
270	18	14	284	113	28	295	183	40
271	101	37	286	197	40	296	95	29
272	133	39	287	156	40	297	122	33
273	176	40	288	167	38	298	179	34
274	152	31	289	132	34	299	211	43
275	123	26	290	186	49	300	161	30
276	126	33	291	98	26	302	119	34
Average of yard							137.96	33.80
Unidentified eggs added							140.36	

TABLE XXVI. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 1, 1910-11, Oregons.

Hen No.	Production		Hen No.	Production		Hen No.	Production	
	1st year	Best 2 months		1st year	Best 2 months		1st year	Best 2 months
A 25	134	33	A 43	176	38	A 64	157	35
A 26	68	22	A 44	28	14	A 65	154	38
A 28	168	39	A 46	102	31	A 66	201	47
A 29	161	35	A 47	205	44	A 68	139	36
A 30	168	42	A 48	138	46	A 70	195	41
A 32	139	30	A 49	71	21	A 71	161	39
A 33	110	30	A 53	81	28	A 72	108	25
A 34	152	35	A 58	165	38	A 73	137	42
A 35	163	43	A 59	86	23	A 74	166	36
A 36	187	48	A 60	177	45	A 185	176	39
A 37	160	35	A 61	257	49	321	163	46
A 39	151	42	A 62	170	42			
A 40	112	35	A 63	159	36			
Average of yard							147.16	36.43

TABLE XXVII. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 9, 1912-13, Oregons.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
C 503	207	50	A 47	205	------	------	O 34	229
C 508	268	56	A 66	201	------	------	O 34	229
C 511	251	58	A 60	177	------	------	O 34	229
C 512	217	49	A 60	177	------	------	O 34	229
C 518	226	50	A 47	205	------	------	O 34	229
C 519	272	52	A 47	205	------	------	O 34	229
C 521	303	57	A 66	201	------	------	O 34	229
C 523	204	46	A 66	201	------	------	O 34	229
C 525	146	36	250	200	------	------	250	200
C 528	214	51	A 66	201	------	------	O 34	229
C 530	184	48	A 60	177	------	------	O 34	229
C 534	204	48	A 61	257	------	------	O 34	229
C 535	200	41	A 61	257	------	------	O 34	229
C 539	191	48	A 61	257	------	------	O 34	229
C 540	123	26	250	200	------	------	250	200
C 541	193	41	A 61	257	------	------	O 34	229
C 542	218	47	A 61	257	------	------	O 34	229
C 543	291	60	250	200	------	------	250	200
C 545	227	50	313	113	------	------	------	------
C 547	250	54	A 66	201	------	------	O 34	229
① ------	219.45	48.40	------	207.45	------	------	------	224.42
② ------	220.80							

① Average of yard. ② Unidentified eggs added.

TABLE XXVIII. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard E, 1913-14, Oregons.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
D 624	242	50	B170	226	250	200	A 111	204
D 625	274	52	Yd. C	*	250	200	A 111	204
D 626	205	43	B 222	188	250	200	A 111	204
D 627	246	52	Yd. C	*	250	200	A 111	204
D 628	220	52	Yd. C	*	250	200	A 111	204
D 629	190	52	B 222	188	250	200	A 111	204
D 630	231	52	B170	226	250	200	A 111	204
D 631	212	49	B170	226	250	200	A 111	204
D 632	228	55	Yd. C	*	250	200	A 111	204
D 633	202	48	Yd. C	*	250	200	A 111	204
D 634	227	55	Yd C	*	250	200	A 111	204
D 635	250	53	B 213	198	250	200	A 111	204
D 636	178	54	B 222	188	250	200	A 111	204
D 637	245	56	H 27M	133	250	200	A 111	204
D 639	185	40	H 53N	168	250	200	A 111	204
D 640	206	49	B 213	198	250	200	A 111	204
D 641	212	40	Yd. C	*	250	200	A 111	204
D 643	92	55	H 16N	184	250	200	A 111	204
D 644	232	49	B 223	146	250	200	A 111	204
D 645	201	49	Yd. C	*	250	200	A 111	204
D 647	278	51	Yd. C	*	250	200	A 111	204
D 648	195	56	B170	226	250	200	A 111	204
D 649	232	49	B 177	193	250	200	A 111	204
D 650	157	42	H 27M	133	250	200	A 111	204
D 652	221	59	Yd. C	*	250	200	A 111	204
D 653	220	51	Yd. C	*	250	200	A 111	204
D 656	176	45	Yd. C	*	250	200	A 111	204
D 657	272	57	B170	226	250	200	A 111	204
D 658	249	55	Yd. C	*	250	200	A 111	204
D 660	216	51	B 223	146	250	200	A 111	204
D 662	171	58	Yd. C	*	250	200	A 111	204
D 663	270	57	B 213	198	250	200	A 111	204
D 664	254	51	B 223	146	250	200	A 111	204
D 665	220	46	B 213	198	250	200	A 111	204
D 667	216	55	B 17	148	250	200	A 111	204
D 670	263	52	Yd. C	*	250	200	A 111	204
D 671	210	47	B 213	198	250	200	A 111	204
D 672	242	54	H 16N	184	250	200	A 111	204
D 673	58	38	Yd. C	*	250	200	A 111	204
D 674	216	54	B 4	217	250	200	A 111	204
D 675	248	54	H 16N	184	250	200	A 111	204
D 676	257	55	B 4	217	250	200	A 111	204
D 678	190	53	B 4	217	250	200	A 111	204
D 679	193	49	H 27M	133	250	200	A 111	204
D 680	185	50	Yd. C	*	250	200	A 111	204
D 681	263	57	H 16N	184	250	200	A 111	204
D 682	178	44	Yd. C	*	250	200	A 111	204
D 683	269	55	B 4	217	250	200	A 111	204
232	210	51	B 223	146	250	200	A 111	204
①	216.44	51.04	....	186.45	......	200.00	......	204.00
②	220.78							

① Average of yard. ② Unidentified eggs added.

*Pen composed of daughters of hen 250. The pen average was 173.66 in first year, and 199.09 in second year. During the first year the lowest record was 116 and the highest 226. During the second year the lowest was 164 and the highest 224.

TABLE XXIX. ANNUAL AND BEST TWO-MONTHS PRODUCTION

Yard 4, 1914-15, Oregons.

Hen No.	Production 1st year	Production Best 2 months	Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
E 215	283	56	C 521	303	A 66	201	B 42	228
E 216	250	59	C 521	303	A 66	201	B 42	228
E 217	254	55	C 521	303	A 66	201	B 42	228
E 218	258	50	C 521	303	A 66	201	B 42	228
E 219	280	54	C 521	303	A 66	201	B 42	228
E 220	247	55	C 521	303	A 66	201	B 42	228
E 221	204	44	C 521	303	A 66	201	B 42	228
E 223	232	51	C 521	303	A 66	201	B 42	228
E 225	224	50	C 521	303	A 66	201	B 42	228
E 227	228	50	C 521	303	A 66	201	B 42	228
①	246.00	52.40	......	303.00	....	201.00	....	228.00
②	250.20							

① Average of yard. ② Unidentified eggs added.

TABLE XXX. ANNUAL AND BEST TWO-MONTHS PRODUCTION

Yard 5, 1914-15, Oregons.

Hen No.	Production 1st year	Production Best 2 months	Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
E 200	200	56	C 543	291	250	200	B 8	246
E 201	192	52	C 543	291	250	200	B 8	246
E 202	162	52	C 543	291	250	200	B 8	246
E 204	160	47	C 543	291	250	200	B 8	246
E 205	239	50	C 543	291	250	200	B 8	246
E 206	152	45	C 543	291	250	200	B 8	246
E 207	193	53	C 543	291	250	200	B 8	246
E 208	226	48	C 543	291	250	200	B 8	246
E 209	241	48	C 543	291	250	200	B 8	246
E 211	205	53	C 543	291	250	200	B 8	246
①	197.00	50.4	....	291.00	......	200.00	......	246.00
②	201.70							

① Average of yard. ② Unidentified eggs added.

TABLE XXXI. ANNUAL AND BEST TWO-MONTHS PRODUCTION

Yard 6, 1914-15, Oregons.

Hen No.	Production 1st year	Production Best 2 months	Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
E 232	145	50	A 66	201	....	......	C 543	291
E 233	212	48	A 66	201	....	......	C 543	291
E 234	286	57	C 507	215	A 27	240	C 543	291
E 235	253	56	C 507	215	A 27	240	C 543	291
E 236	156	52	A 66	201	....	......	C 543	291
E 237	235	48	A 66	201	....	......	C 543	291
E 238	239	54	B 42	228	....	......	C 543	291
E 239	159	47	A 66	201	....	......	C 543	291
E 240	257	53	C 507	215	A 27	240	C 543	291
E 241	212	52	C 507	215	A 27	240	C 543	291
E 242	161	47	C 507	215	A 27	240	C 543	291
E 243	219	53	C 547	250	A 66	201	B 42	228
E 244	177	44	A 66	201	....	......	C 543	291
E 246	245	51	A 66	201	....	......	C 543	291
①	211.14	50.86	....	211.43	....	233.50	......	286.51
②	217.27							

① Average of yard. ② Unidentified eggs added.

TABLE XXXII. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard J, 1914-15, Oregons.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
E 101	178	51	Yd. E	......	....	......	A 66	201
E 102	241	56	Yd. E	......	....	......	A 66	201
E 103	162	37	C 539	191	A 61	257	B 8	246
E 104	263	51	Yd. E	......	....	......	A 66	201
E 105	181	46	Yd. E	......	....	......	A 66	201
E 106	238	52	Yd. E	......	....	......	A 66	201
E 107	213	53	C 490	231	A 61	257	B 8	246
E 108	212	46	Yd. E	......	....	......	A 66	201
E 109	200	46	Yd. E	......	....	......	A 66	201
E 110	233	49	Yd. E	......	....	......	A 66	201
E 112	244	47	Yd. FX	......	....	......	A 27	240
E 113	224	51	C 539	191	A 61	257	B 8	246
E 114	262	54	C 470	211	A 47	205	H12N	144
E 115	301	58	B 42	228	....	......	C 543	291
E 116	149	34	Yd. FX	......	....	......	A 27	240
E 117	176	40	Yd. E	......	....	......	A 66	201
E 118	258	48	B 42	228	....	......	C 543	291
E 119	245	54	C 508	268	A 66	201	C 543	291
E 120	77	30	Yd. E	......	....	......	A 66	201
E 121	180	48	C 528	214	A 66	201	B 42	228
E 122	199	45	Yd. E	......	....	......	A 66	201
E 123	293	56	Yd. E	......	....	......	A 66	201
E 124	238	49	C 537	219	A 51	209	C 543	291
E 125	188	46	B 8	246	250	200	B 42	228
E 126	186	54	C 514	214	A 45	215	C 543	291
E 127	274	56	C 503	207	A 47	205	H12N	144
E 128	150	45	C 425	235	....	......	B 42	228
E 129	233	49	Yd. E	......	....	......	A 66	201
E 130	282	57	Yd. E	......	....	......	A 66	201
E 131	162	41	C 539	191	A 61	257	B 8	246
E 132	261	57	Yd. E	......	....	......	A 66	201
E 133	228	50	Yd. E	......	....	......	A 66	201
E 134	182	46	Yd. E	......	....	......	A 66	201
E 135	230	46	B 222	188	250	200	B 42	228
E 136	285	59	Yd. E	......	....	......	A 66	201
E 138	309	57	C 584	119	O 34	229	H12N	144
E 139	191	40	C 534	204	A 61	257	C 543	291
E 141	228	47	Yd. E	......	....	......	A 66	201
E 143	155	45	C 547	250	A 66	201	B 42	228
E 144	154	46	Yd. E	......	....	......	A 66	201
E 145	195	44	Yd. E	......	....	......	A 66	201
E 146	208	47	Yd. E	......	....	......	A 66	201
E 147	241	58	C 503	207	A 47	205	H12N	144
E 148	181	44	Yd. E	......	....	......	A 66	201
E 149	159	47	Yd. E	......	....	......	A 66	201
E 150	191	53	Yd. E	......	....	......	A 66	201
E 152	213	53	Yd. E	......	....	......	A 66	201
E 153	213	53	Yd. E	......	....	......	A 66	201
E 154	280	57	Yd. E	......	....	......	A 66	201
E 155	253	51	Yd. E	......	....	......	A 66	201
E 156	284	54	C 518	226	A 47	205	H12N	144
E 157	266	54	C 512	217	A 60	177	A 27	240
E 159	171	51	Yd. E	......	....	......	A 66	201
E 163	194	46	Yd. E	......	....	......	A 66	201
E 165	236	54	C 537	219	A 51	209	C 543	291
E 166	147	43	C 547	250	A 66	201	B 42	228
1554	270	56	D 618	188	Yd. C	......	B 170	226
1604	223	46	C 481	239	Yd. 1	......	H12N	144
①	217.24	49.19	....	215.24	....	217.40	......	214.31
②	219.22							

① Average of yard. ② Unidentified eggs added.

TABLE XXXIII. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 10, 1915-16, Oregons.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
F 566	286	58	D 269	276	B 42	228	C 516	267
F 567	271	56	Yd. M	*	....	......	C 521	303
F 568	222	52	Yd. M	*	....	......	C 521	303
F 569	208	50	Yd. M	*	....	......	C 521	303
F 571	251	51	Yd. M	*	....	......	C 521	303
F 572	245	48	Yd. M	*	....	......	C 521	303
F 574	233	44	Yd. M	*	....	......	C 521	303
F 575	156	40	Yd. M	*	....	......	C 521	303
F 576	226	53	Yd. M	*	....	......	C 521	303
F 577	226	54	Yd. M	*	....	......	C 521	303
F 578	200	46	D 614	272	B 4	217	C 516	267
F 579	256	49	Yd. M	*	....	......	C 521	303
F 580	267	53	Yd. M	*	....	......	C 521	303
①	234.39	50.31	....	274.00	....	222.50	....	297.46
②	237.77							

① Average of yard. ② Unidentified eggs added.
* Pen of high producing birds laying from 190 to 278.

TABLE XXXIV. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard 7, 1917-18, Oregons.

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
H 589	270	56	F 567	271	Yd. M	......	C 521	303
H 590	284	55	E 827	203	C 488	268	C 521	303
H 591	244	51	F 572	245	Yd. M	......	C 521	303
H 592	265	50	E 220	247	C 521	303	D 269	276
H 593	189	43	F 566	286	D 269	276	C 521	303
H 594	240	49	F 568	222	Yd. M	......	C 521	303
H 595	218	48	F 808	262	E 217	254	E 123	293
H 596	251	45	F 813	206	E 216	250	E 123	293
H 597	210	51	F 566	286	D 269	276	C 521	303
H 598	251	54	F 846	265	Yd. 7	......	E 123	293
H 599	274	50	F 281	268	Yd. M	......	A 60	177
H 600	224	53	C 547	250	A 66	201	C 521	303
①	243.33	50.41	....	250.92	....	261.14	....	287.75
②	246.91							

① Average of yard. ② Unidentified eggs added.

TABLE XXXV. ANNUAL AND BEST TWO-MONTHS PRODUCTION
Yard H, 1917-18, Oregons

Hen No.	Production		Dam	Eggs 1st yr.	D.D.	Eggs 1st yr.	S.D.	Eggs 1st yr.
	1st year	Best 2 months						
H 701	177	50	C 547	250	A 66	201	C 521	303
H 703	283	54	E 220	247	C 521	303	D 269	276
H 704	191	55	C 547	250	A 66	201	C 521	303
H 705	191	47	C 547	250	A 66	201	C 521	303
H 706	208	51	Yd. 13	....	....	......	A 60	177
H 707	243	51	E 827	203	C 488	268	C 521	303
H 708	200	45	F 567	271	Yd. M	......	C 521	303
H 709	229	55	Yd. 8	....	....	......	B 14	215
H 710	170	50	E 229	241	C 521	303	C 521	303
H 713	276	58	Yd. 13	....	....	......	A 60	177
H 714	221	51	E 285	234	C 521	303	D 269	276
H 715	251	54	E 285	234	C 521	303	D 269	276
H 716	203	48	Yd. 13	....	....	......	A 60	177
H 717	252	52	E 282	233	C 521	303	D 269	276
H 718	223	56	Yd. 9	....	C 521	303	E 178	299
H 719	224	54	Yd. 13	....	....	......	A 60	177
H 721	226	50	F 575	156	Yd. M	......	C 521	303
H 722	256	51	Yd. 13	....	....	......	A 60	177
H 723	236	54	E 827	203	C 488	268	C 521	303
H 724	177	44	F 554	234	C 521	303	E 178	299
H 725	236	54	Yd. 8	....	....	......	B 14	215
H 726	231	54	F 575	156	Yd. M	......	C 521	303
H 728	269	55	E 827	203	C 488	268	C 521	303
H 729	173	52	Yd. 9	....	C 521	303	E 178	299
H 731	230	51	Yd. 9	....	C 521	303	E 178	299
H 732	207	50	F 575	156	Yd. M	......	C 521	303
H 733	192	52	F 555	132	C 521	303	E 178	299
H 734	175	56	G 515	274	C 521	303	C 590	193
H 735	225	53	E 229	241	C 521	303	C 521	303
H 736	235	55	F 555	132	C 521	303	E 178	299
H 737	222	58	Yd. 9	....	C 521	303	E 178	299
H 740	227	57	Yd. 8	....	....	......	B 14	215
H 741	204	50	F 554	234	C 521	303	E 178	299
H 742	260	49	Yd. 13	....	....	......	A 60	177
H 743	170	55	Yd. 9	....	C 521	303	E 178	299
H 745	213	48	E 157	266	C 512	217	E 123	293
H 746	216	50	F 916	213	B 14	215	E 123	293
H 747	244	52	D 328	215	B 13	206	E 123	293
H 749	229	51	F 916	213	B 14	215	E 123	293
H 750	261	56	F 566	286	D 269	276	C 521	303
H 751	253	54	E 123	293	Yd. E	......	E 123	293
H 752	202	47	E 136	285	Yd. E	......	E 123	293
H 753	209	53	Yd. 9	....	C 521	303	E 178	299
H 755	228	51	E 130	282	Yd. E	......	E 123	293
H 756	192	47	E 123	293	Yd. E	......	E 123	293
H 757	213	51	F 568	222	Yd. M	......	C 521	303
H 758	203	49	E 176	242	B 14	215	E 123	293
H 759	271	61	F 846	265	Yd. 7	......	E 123	293
H 760	291	59	F 566	286	D 269	276	C 521	303
H 761	196	56	E 130	282	Yd. E	......	E 123	293
H 762	304	58	E 112	244	Yd FX	......	E 123	293
H 763	229	49	F 873	250	B 8	246	S 123	293
H 764	189	47	D 328	215	B 13	206	E 123	293
H 767	226	55	D 269	276	B 42	228	C 521	303
H 768	247	49	D 269	276	B 42	228	C 521	303
H 769	255	54	Yd. 9	....	C 521	303	E 178	299
H 770	258	58	Yd. 9	....	C 521	303	E 178	299
H 771	269	55	F 281	268	Yd. M	......	A 60	177
H 772	189	54	G 515	274	C 521	203	C 590	193
H 773	270	51	Yd. 13	....	C 521	303	A 60	177
H 774	123	38	Yd. 13	....	....	......	A 60	177
H 775	228	52	Yd. 13	....	....	......	A 60	177
H 776	225	59	E 515	245	C 56	210	A 27	240
①	224.38	52.30	....	237.79	....	269.44	....	269.62
②	228.57							

① Average of yard. ② Unidentified eggs added.

SUMMARIES

Barred Plymouth Rocks. A summary is given in Table XXXVI of the Barred Plymouth Rocks, showing egg records for first twelve months of laying of the pullets, their dams' dams, sires' dams where known for the different years. This gives the record of 517 pullets in their first year, and the average for all of the years, for eight generations, including the foundation stock, together with the records of ancestry. Beginning with the foundation stock in 1908-09, and ending with the eighth generation, there is an increase in the production per hen of 128.49 eggs, or a percentage increase of 149.16. If we make the starting point 1909-10 in view of the fact that the pullets of the previous year were selected from different breeders and were not reared at the Station as all subsequent pullets were, we find the increase to be 93.95 eggs, or 77.78 percent.

Yard 15 (Table III), though not pedigreed, were from hens of the first year after being culled. That is to say, one-third of the poorest of the first year were culled out, yard-15 pullets being therefore from the best two-thirds of the flock. This may have had some influence in raising the production of yard 15. The males were of unknown pedigree, but it may have "happened" that they were from good layers. The pullets in this yard, in addition, were of a uniform age, and came to laying maturity at a favorable time, and in this respect had the advantage to some extent over yards of later years.

The first records of pedigreed pullets are given in yard 6, 1912-13 (Table IV). The pullets of this yard were from dams with an average record of 210.94, and sires' dams 194.79.

It is seen that there is a considerable increase in egg yield in the first-generation pullets from high-producing pedigreed stock. The increase is not so great in later generations. Where the increase from unselected stock to pedigreed stock of the first generation is about 56 eggs the increase from the first generation of pedigreed stock to the fourth generation of pedigreed pullets is about 24 eggs. While the increases in subsequent generations are satisfactory, the largest increase is shown in the first generation of selected stock. The influence of the immediate parent is apparently more pronounced than that of other

TABLE XXXVI. SUMMARY OF FIRST YEAR'S PRODUCTION OF BARRED PLYMOUTH ROCKS (IN AVERAGE PER HEN)

Yard	Year	No. of birds	Pullets	Unidentified eggs added	Best two months	Dams	Dams' dams	Sires' dams
4 and 5	1908-09	92	82.67	86.14	31.29	....	....	....
6	1909-10	28	117.64	120.68	33.71	....	....	....
15	1910-11	42	161.78	164.28	38.48	....	....	....
6	1912-13	38	174.13	178.16	44.74	210.94	....	194.79
7	1912-13	37	177.43	180.97	45.22	181.37	202.44	185.96
8	1912-13	33	171.69	174.18	44.30	196.76	....	183.85
B	1913-14	52	178.75	185.00	46.88	193.86	215.05	220.52
C	1913-14	51	169.41	175.59	46.57	182.32	205.75	224.57
L	1914-15	33	176.36	185.78	45.27	181.33	208.71	216.19
P	1914-15	38	184.06	189.01	46.69	213.84	214.81	231.68
18	1916-17	11	194.45	201.90	51.18	247.36	197.44	223.13
F	1917-18	62	202.40	214.63	47.19	200.23	229.47	244.58
Average		517	158.57	164.09	42.25	198.11	212.45	217.29

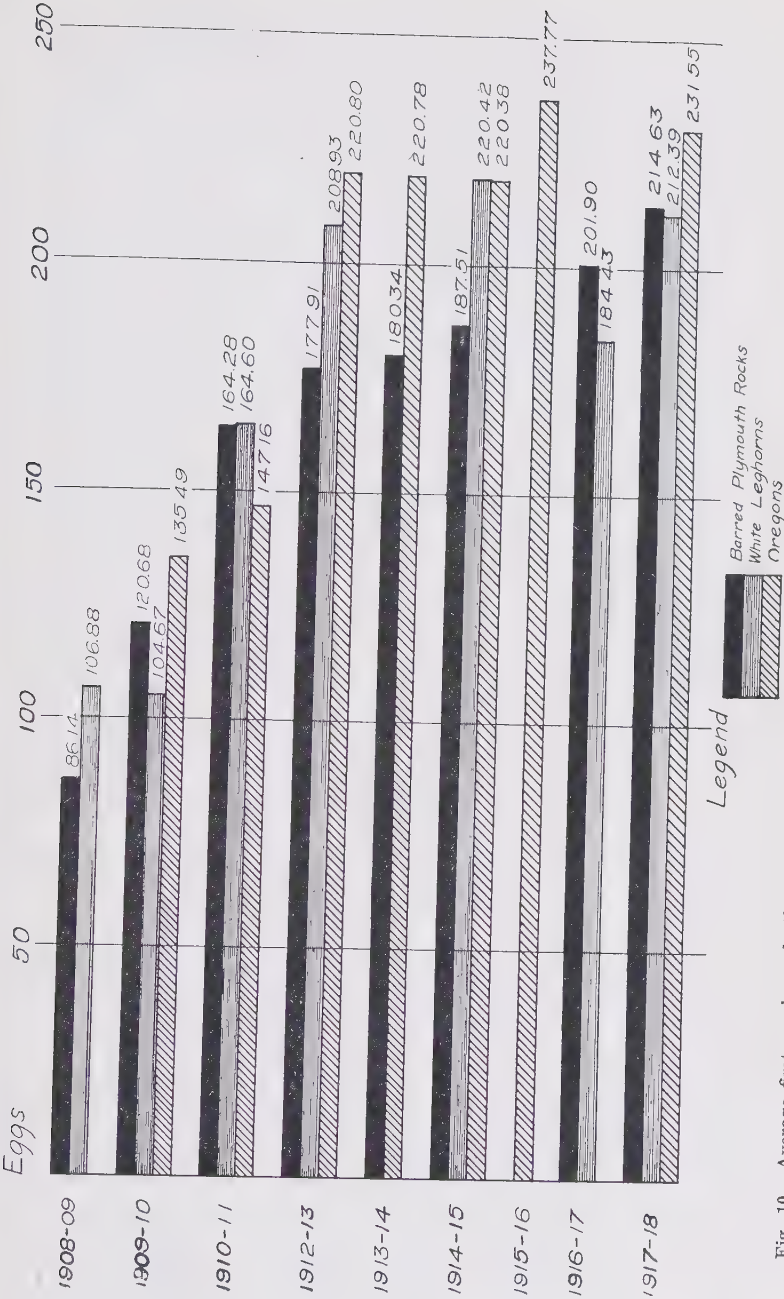


Fig. 10. Average first year's production of Barred Plymouth Roc ks, Leghorns, and Oregons in the different years of the experiment, showing increase in production in different generations as a result of selection of breeding stock on basis of first year's production records.

ancestors. On the other hand, we see from the records that the more high-record ancestors there are, the higher is the flock average. It is expected, of course, that as the maximum possible hen production is approached, whatever it is, the rate of increase must necessarily be lower. In other words, as production rises beyond the mean of the breed or race, there is a stronger pull backward and increases will naturally be slower.

White Leghorns. A summary for the White Leghorns is given in Table XXXVII. The total number of hens was 386. The average of the foundation flock was 106.88 eggs a hen. In the last year yards F and G (Tables XXII and XXIII), 116 hens, averaged 212.39 a hen, which is a percentage increase of 98.72. In the third year, with only ten hens, the average was high for unselected hens, but the fact that in this yard hen A27 of high record was "found" accounts for some of the increase. These hens were not pedigreed but were from the foundation stock in the second year after the poorest layers of the first year had been culled out.

In the main, the results with the Leghorns agree with those of the Plymouth Rocks. In the first generation of pedigreed stock there was a large increase. In the second year of pedigreed stock, there was also a considerable increase. After that the increase was not particularly noteworthy. The variation in the increase in different years is considerable, and does not conform to any statistical conception of breeding.

Probably various factors account for these differences. In yard 3, 1914-15 (Table XVII), the influence of the male was plainly apparent. The breeding quality or prepotency of this male will be discussed in the report on the influence of the male. There was in this pen a 302-egg hen and several sisters and half sisters with high records. The decrease shown in yards P and Q has already been referred to as probably due largely to environmental conditions. It will be noticed also that the production of the dams averaged lower than that of other pedigreed yards, though the sires' dams averaged high. In every year, however, there was a considerable increase over the production of the non-pedigreed flock.

TABLE XXXVII. SUMMARY OF FIRST YEAR'S PRODUCTION OF WHITE LEGHORNS (IN AVERAGE PER HEN)

Yard	Year	No. of birds	Pullets	Unidentified eggs added	Best two months	Dams	Dams' dams	Sires' dams
4 and 5	1908-09	50	106.14	106.88	32.54	....	....	....
9..........	1909-10	21	104.67	104.67	30.71	....	....	....
1..........	1910-11	10	164.60	164.60	41.30	....	....	....
9..........	1912-13	14	207.85	208.93	47.64	223.85	....	229.00
3..........	1914-15	16	227.00	230.12	51.19	242.19	222.33	233.13
O..........	1914-15	42	212.86	216.72	49.24	236.97	221.68	237.25
P..........	1916-17	49	187.55	188.96	47.61	209.74	247.27	251.71
Q..........	1916-17	57	169.84	172.65	44.77	211.75	241.56	253.74
15..........	1916-17	11	215.00	225.27	51.63	227.64	245.09	242.18
F..........	1917-18	60	218.21	222.22	47.78	235.42	239.78	302.00
G..........	1917-18	56	199.63	201.85	48.57	234.50	247.95	236.81
Average..........		386	181.71	184.25	44.76	224.69	238.52	256.33

A flock of sixty pullets in yard F, 1917-18 (Table XXII) gave the very satisfactory average of 222.22 eggs a hen. These pullets were all sired by males from a dam with record of 302 eggs and grandson of the sire of yard-3 pullets.

The production of the pullet progeny, it will be seen, averaged lower than that of either the dam, dams' dams, or sires' dams in all cases. But the difference is less between the pullets and dams than between the pullets and sires' dams.

The best two months' production shows an increase of 48 percent from the first year to the last year. The rate of increase in each year of pedigreed progeny, as in the case of the Plymouth Rocks, does not bear a close relation to the increase in number of generations of pedigreed ancestors.

Cross-breds or Oregons. A summary of the cross-breds or Oregons in Table XXXVIII shows that the second generation, yards 7 and 8 (Tables XXIV and XXV), averaged 135.49 eggs, and the seventh or last generation, yards 7 and H, averaged 231.55 eggs a hen, an increase of 96.06 eggs or a percentage increase of 70.89 (Tables XXXIV and XXXV). If we figure from the foundation stock of White Leghorns and Barred Plymouth Rocks, the increase is over 150 percent.

The increase in the best two months, from the first generation of crosses to the last generation of Oregons is 58.05 percent, giving additional evidence that high-laying capacity has been inherited.

There was a very marked increase from the unselected stock to the first generation of pedigreed stock, and the increase in subsequent generations is considerable, though not so marked. This agrees with the results secured with Barred Plymouth Rocks and White Leghorns.

On the whole the flock increases are much greater for the Oregons than for the Leghorns or Plymouth Rocks, if we calculate from the foundation stock. The first cross shows a considerable increase over both parent breeds. In the absence of selection, the only explanation for this increase is that there was an increase in the vigor, which was responsible for the increased production. The largest increase, however, came in subsequent generations of pedigreed stock, where the record shows high production of the ancestors. In this latter respect also, the results agree with those of the pure Leghorns and Barred Plymouth Rocks, the immediate parents apparently exercising a greater influence on the production of the flock than other ancestors.

TABLE XXXVIII. SUMMARY OF FIRST YEAR'S PRODUCTION OF OREGONS (IN AVERAGE PER HEN)

Yard	Year	No. of birds	Pullets	Unidentified eggs added	Best two months	Dams	Dams' dams	Sires' dams
7	1909-10	33	129.94	131.06	32.09	....	....	....
8	1909-10	30	137.96	140.36	33.80	....	....	....
1	1910-11	37	147.16	147.16	36.43	....	....	....
9	1912-13	20	219.45	220.80	48.40	207.45	....	224.42
E	1913-14	49	216.44	220.78	51.04	186.45	200.00	204.00
4	1914-15	10	246.00	250.20	52.40	303.00	201.00	228.00
5	1914-15	10	197.00	201.70	50.40	291.00	200.00	246.00
6	1914-15	14	211.14	217.27	50.86	211.43	233.50	286.51
J	1914-15	58	217.24	219.22	49.19	215.24	217.40	214.31
10	1915-16	13	224.39	237.77	50.31	274.00	222.50	297.43
7	1917-18	12	243.33	246.91	50.41	250.92	261.14	287.75
H	1917-18	63	224.38	228.57	52.30	227.79	269.44	269.62
Average		349	197.58	201.05	45.95	227.51	226.15	240.92

In the first generation of pedigreed Oregons, the flock average was more than the average of the dams and slightly less than the average of the sires' dams. In the next year the flock averaged 220.78 eggs, while the dam's average was 186.45, dams' dam 200, and sire's dam 204. In this case, there was an actual increased production over the parent stock on both sides. This happened in one other case, that of yard J, 1914-15 (Table XXXII), the pullets, 58 in number, averaging 219.22 eggs, dams 215.24, dams' dams 217.4, and sire's dams 214.31. Here we have an actual increase in production over the apparent capacity of the ancestors.

Taking the average of all flocks and hens where the breeding stock is selected among the highest producers of the flock, their pullet progeny has a lower average flock record than the average of the ancestors.

There are many cases, however, in our records, where the individual production of the hen is greater than the ancestors, even though the latter are high producers. In yard 9, 1912-13 cited above (Table XXVII), there are six hens in twenty with records exceeding the records of both dam and sire's dam, the highest record being 303, and dam's record 201 and sire's dam 229. The second highest was 291 eggs with dam's record of 200 and sire's record the same.

In yard E 1913-14 (Table XXVIII) is the rather remarkable record of 49 pullets, with average production considerably in excess of the production of either the dam, dam's dams, or sire's dam. The same male was sire of all the pullets. On the other hand, in yard 5 (Table XXX), ten pullets averaged 201.7, while the dam laid 291, dam's dam 200, sire's dam 246.

In yard J (Table XXXII), containing 58 pullets, the average production is higher than that of the dam, dams' dam, or sires' dams. This is another case in which the production was higher than that of high-record ancestry. In this yard, however, there were six pullets, from a low-record sire's dam and high dam, except in one case where the dam was a low hen with production of 119 eggs. From this low-record hen and low-record sire's dam, the highest egg record of the yard was secured; namely, 309 eggs. The pedigree of the sire's dam, whose record was 144 eggs, extends farther back through several generations of very low producers, as shown in Table XLV.

From this table it might be proved, both that high production is and that it is not inherited. If we take the average of all the pullet flock and the average of the ancestors, it is clear that high production is inherited. But if certain individuals be selected from the table, it could be shown that there was both transmission and non-transmission of laying qualities. Certain individuals apparently inherited high production from high producers, and certain other individuals apparently inherited low production. But when the average of all the flock is taken, in connection with the production of former generations of the strain, there can be no question that the factor of high production was inherited.

If there was lack of vigor in the parent stock and the first cross restored the vigor, then the production of the first generation of crosses, which was 135.49 eggs, should represent their actual inherited egg-laying capacity, and the increase from the first generation to the seventh of the crosses or "Oregons" represents the effect of selection of breeding stock, based on high production records. In that case, crossing alone did not produce high-record layers, the greatest increase coming from subsequent selection.

While crossing evidently increased the vigor and to that extent increased production, it is not assumed that the production of the first crosses was greater than may be secured from pure breds of good vigor; but in subsequent generations when trap-nest selection was practiced, a much greater increase was secured. It would appear that the opinion often expressed, that crossing usually gives good results in the first generation, but that in subsequent crosses there is reversion or a decrease, is not necessarily true. The increase in production of the pure White Leghorns and Barred Plymouth Rocks was secured not by maintaining merely breed purity, but by selection within the breed, or the use of breeding stock with high individual production records. Nor did we find that crossing the crosses brought about deterioration, but by similar selection of breeding stock we secured, on the contrary, a higher production than from the first generation of crosses. Inbreeding was avoided, because of the danger of defeating the purpose we had in view in crossing, that of increasing the vigor.

SUPPLEMENTARY EXPERIMENTS

In 1914 the Station placed with the poultry department of the Oregon State Hospital 100 pullets from yard E, 1913-14, Oregons. Their date of hatch was March 15. The State institution also secured eggs from the same flock from which 80 additional pullets were reared, which were hatched June 24. These two flocks were kept under conditions of housing and yarding similar to those at the Experiment Station and the same feeding system was followed. This work at the Oregon State Hospital was made possible through the cooperation of the superintendent, Dr. R. E. Lee Steiner. The record work was supervised by the head of the Poultry department of the Experiment Station, who also selected the breeding stock. The Poultry department of the State Hospital was put in direct charge of C. M. Wilcox, a graduate assistant of the Station's Poultry department. After Mr. Wilcox's death in the war service, W. H. Hart and A. D. Zinser had charge.

TABLE XXXIX. FIRST YEAR'S PRODUCTION 1914-15, OREGONS, OREGON STATE HOSPITAL

Pullet No.	Yard 1 first year	Pullet No.	Yard 2 first year	Pullet No.	Yard 3 first year
12	275	48	278	82	281
16	258	40	267	75	276
11	253	57	263	90	266
14	252	47	254	94	257
7	250	55	250	100	253
5	250	39	248	91	252
23	245	44	246	71	248
19	245	45	245	69	245
15	244	58	244	74	244
6	235	61	244	83	240
30	227	63	238	70	239
26	225	66	238	99	239
31	225	49	237	92	238
32	223	42	237	89	237
22	223	52	235	97	234
20	222	60	234	77	225
10	220	62	228	96	220
29	220	43	226	87	215
9	212	59	219	78	214
27	207	64	214	81	213
4	202	51	213	72	211
3	201	35	211	68	209
8	201	53	210	93	207
24	200	38	206	76	206
1	194	50	201	85	205
33	193	67	198	73	195
2	186	54	196	80	195
28	183	36	193	86	188
17	181	46	190	98	176
18	180	65	188	79	170
21	177	37	185	95	162
25	163	56	177	84	156
13	161				
Average	216.15	Average	225.41	Average	222.38

Of the 100 March-hatched pullets 97 completed the full laying year, while 75 of the 80 June-hatched pullets finished the laying year. The production of the two flocks is shown in tables XXXIX and XL. The first flock, which occupied yards 1, 2, and 3, averaged in the first year 221.26, with high record of 281 and low record of 156. The 75 June-hatched pullets in yards 4 and 5 averaged in the first year 219.41, with high record of 303 and low record of 147 eggs.

The pullets of yards 1, 2, and 3 were from yard-E dams, which averaged 220.78 eggs. They were not individually pedigreed, however. It will be noted that the sires' dam A66 was the dam of C521, record 303 eggs. The dams' dams were yard C, record 173.66 eggs in the first year and 199.09 in the second, the low first-year record being due

TABLE XL. FIRST YEAR'S PRODUCTION 1914-15, OREGONS, OREGON STATE HOSPITAL

Pullet No.	Yard 4 first year	Dam	First year	Pullet No.	Yard 5 first year	Dam	First year
102	303	D 681	263	174	286	D 670	263
131	296	D 657	272	159	278	D 683	269
105	292	D 683	269	146	267	D 684	
103	291	D 674	216			or D626	......
112	284	D 625	274	142	263	D 637	245
114	272	D 637	245	143	260	D 625	274
136	257	D 670	263	180	248	D 683	269
128	253	D 627	246	144	247	D 635	250
133	253	D 670	263	145	247	D 680	185
101	248	D 624	242	172	243	D 671	210
123	245	D 637	245	147	238	D 663	270
120	242	D 637	245	167	234	D 665	220
124	242	D 627	246	161	231	D 633	
130	238	D 656	176			or D625	......
109	237	D 680	185	173	230	D 684	
108	233	D 657	272			or D626	......
118	230	D 653	220	155	227	D 650	157
125	223	D 684		150	222	D 678	190
		or D626	......	149	217	D 662	171
106	221	D 636	178	152	217	D 679	193
119	218	D 625	274	163	217	D 631	212
135	212	D 670	263	171	216	D 650	157
126	211	D 675	248	148	213	D 671	210
113	210	D 624	242	154	213	D 639	185
129	208	D 675	248	179	207	D 671	210
134	208	D 671	210	141	202	D 624	242
115	207	D 629	191	168	197	D 631	212
104	207	D 678	190	166	194	D 665	220
117	205	D 655	205	156	191	D 681	263
122	200	D 625	274	178	191	D 660	216
111	197	D 662	171	160	189	D 684	
140	195	D 684				or D626	......
		or D626	......	170	188	D 649	232
110	194	D 629	191	153	178	D 635	250
116	190	D 679	193	175	170	D 663	270
127	185	D 679	193	176	170	D 629	191
138	178	D 679	193	151	167	D 672	242
137	173	D 625	274	177	164	D 636	178
107	167	D 635	274	157	151	D 631	212
121	157	D 633	202	165	147	232	210
132	154	D 684	218				
Average	224.00		219.85	Average	214.44		221.19

TABLE XLI. FIRST YEAR'S PRODUCTION 1915-16, OREGONS, OREGON STATE HOSPITAL

Pullet No.	Yard 6 first year	Dam	First year	Pullet No.	Yard 6 first year	Dam	First year
317	302	14	252	332	232	8	201
285	284	16	258	366	232	100	253
423	282	76	206	421	232	85	205
217	281	91	252	447	232	61	244
234	281	81	213	432	231	69	245
433	280	16	258	287	230	32	223
369	279	1	194	398	229	71	248
407	277	31	225	451	229	15	244
224	276	63	238	314	227	50	201
341	275	79	170	413	227	26	225
203	273	82	281	209	226	89	237
278	272	93	207	275	226	2	186
215	265	75	276	364	226	54	196
291	265	95	162	367	226	11	253
308	264	76	206	281	225	22	223
411	264	96	220	252	225	87	215
435	264	59	219	213	224	100	253
343	263	25	163	309	224	31	225
402	263	82	281	391	224	27	207
261	262	40	267	406	224	22	223
452	262	12	275	300	223	44	246
420	261	87	215	331	223	36	193
259	259	94	257	254	223	94	257
211	257	82	281	339	223	1	194
294	256	12	275	246	222	23	245
443	256	59	219	225	221	58	244
276	254	71	248	279	221	78	214
256	253	74	244	438	221	91	252
271	253	93	207	257	220	20	222
292	253	57	263	289	220	76	206
320	253	94	257	297	218	16	258
340	251	11	253	418	218	27	207
251	250	12	275	210	217	92	238
201	248	23	245	266	217	14	252
221	248	82	281	359	217	26	225
375	248	15	244	319	216	75	276
307	247	68	209	404	216	46	190
349	247	81	213	441	216	4	202
429	247	64	214	207	215	26	225
361	246	16	258	267	215	13	161
448	246	48	278	286	215	77	225
449	246	72	211	365	215	35	211
229	245	82	281	370	215	83	240
274	245	45	245	394	215	5	250
227	245	87	215	299	214	69	245
395	245	42	237	330	214	35	211
337	244	8	201	345	214	10	220
235	243	71	248	204	213	5	250
218	242	93	207	306	213	51	213
219	242	28	183	444	213	67	198
226	242	90	266	352	212	9	212
327	242	82	281	321	211	23	245
212	239	68	209	368	210	42	237
293	239	75	276	233	209	75	276
344	239	98	176	255	209	91	252
371	239	59	219	405	209	42	237
236	238	87	215	250	208	67	198
242	237	8	201	419	208	46	190
357	237	1	194	237	206	57	263
231	236	77	225	315	206	15	244
283	236	59	219	335	206	39	248
362	236	76	206	355	206	75	276
220	235	81	213	414	206	46	190
393	235	90	266	346	204	67	198
228	234	16	258	351	203	65	188
272	234	75	276	303	202	13	161
347	234	77	225	354	202	45	245
342	233	45	245	442	202	44	246
428	233	6	235	268	201	14	252
273	232	11	253	392	201	13	161
277	232	69	245	403	201	16	258
				445	201	13	161

TABLE XLI.—*Continued.*

Pullet No.	Yard 6 first year	Dam	First year	Pullet No.	Yard 6 first year	Dam	First year
310	199	53	210	205	180	39	248
422	199	44	246	376	178	72	211
334	198	86	188	245	177	99	239
416	198	67	198	270	176	53	210
238	197	38	206	358	176	90	266
263	196	8	201	248	173	52	235
401	196	91	252	208	172	69	245
232	195	8	201	440	170	40	267
280	195	22	223	425	168	85	205
328	195	15	244	312	166	35	211
329	195	81	213	426	164	99	239
434	195	85	205	377	163	43	226
239	194	77	225	288	161	58	244
264	194	31	225	304	159	51	213
350	193	38	206	313	159	23	245
318	192	20	222	417	159	76	206
269	191	76	206	260	157	53	210
222	189	49	237	372	152	59	219
296	189	94	257	243	149	90	266
333	188	42	237	262	141	59	219
427	187	82	281	298	137	51	213
453	187	50	201	374	135	8	201
240	184	38	206	202	131	8	201
265	184	14	252	431	131	33	193
305	184	60	234	446	126	48	278
409	183	11	253				
408	182	58	244	Average	218.78	....	229.17

TABLE XLII. SUMMARY OF FIRST AND SECOND YEARS OF 77 DAMS OF YARD SIX AND THEIR PULLETS

Groups	Dams			Dam's Dams	Daughters			
	No. of hens	Average Production		Average Production	No. of Hens		Average Production	
		1st year	2nd year	1st year	1st year	2nd year	1st year	2nd year
All dams and daughters	77	223.76	155.42	220.78*	195	141	218.78	155.97
251- to 300-egg dams	13	263.92	175.16	220.78	50	41	229.26	163.61
201- to 250-egg dams	49	225.67	152.93	220.78	120	81	214.15	150.87
151- to 200-egg dams	15	182.73	143.7	220.78	25	19	220.08	161.21

*Yard average.

TABLE XLIII. SUMMARY OF FIRST YEAR'S PRODUCTION AND BEST TWO MONTHS, OREGONS, OREGON STATE HOSPITAL

Yard	Year	No. hens	First year	Best 2 months	Dam's average	Sire's dam's average
					Yd. E	
1	1914-15	33	216.15	48.88	(220.78)	201.00
2	1914-15	32	225.41	49.66	(220.78)	201.00
3	1914-15	32	222.38	49.72	(220.78)	201.00
4	1914-15	39	224.00	50.46	219.85	201.00
5	1914-15	36	214.44	51.56	221.19	201.00
6	1915-16	195	218.78	50.73	229.17	291.00

to lateness of hatch and other conditions. The high second-year record indicates high laying capacity. These pullets were the fourth generation from high-record pedigreed stock.

The June-hatched pullets of yards 4 and 5 were from the same yard E, but they had individual hen pedigrees. In other respects their pedigrees are the same as yards 1, 2, and 3.

In the winter of 1915 the pullets of yards 1, 2, and 3 were mated to males whose dam was C543, record 291 eggs. From this mating 195 pullets were produced and trap-nested. Their production is shown in Table XLI. They were from 77 of the hens in the yard, each chick being pedigreed. The dams averaged 223.76 eggs and the daughters averaged 218.78, while the dams' dams averaged 220.78. In the second year 141 of these pullets were kept over and averaged 155.97 in the second year, while their dams averaged 155.42.

In Table XLII have been grouped the 77 dams of 195 pullets of yard 6. It is seen that 13 of the dams laid an average of 263.92 eggs and within a range of 251 to 300 eggs inclusive; 49 averaged 225.67 and laid within 201 to 250, while 15 averaged 182.73 and laid within 151 to 200. Their second-year record is also given.

In the same table is shown the production of the 195 pullets for the first year, and the second-year production of 141 remaining. They are also grouped according to dams, the thirteen highest-record dams having 50 daughters with average record of 229.26 in first year. The second group of 49 dams produced 120 pullets with average record of 214.15, and the third group of 15 dams produced 25 pullets averaging 220.08 in first year.

There is no significant difference in the production of the pullets from the different groups of dams, the fifteen dams averaging 182 plus eggs producing pullets of but slightly lower average than the highest group of dams with average egg production of 263 plus, while the pullets from the second group of dams averaging 225 plus averaged a trifle less than the pullets from the lowest group of dams.

The dams, however, are practically all of high record and of the same breeding, and were mated to sires from the same dam. The records of the pullets in this case appear to follow the average production of the strain or of the ancestors of the female line. This result emphasizes the importance of the strain or of long high-production pedigree, rather than the value of the immediate parent.

It is rather remarkable how closely the records of the State Hospital flocks follow those of the Experiment Station flocks. Under different environment these flocks at the State Hospital showed practically the same production as the Station's flocks of similar breeding, indicating, as in the case of the Station flocks, transmission of high fecundity. The influence of the male whose dam laid 191 eggs, did not result in raising the production of the pullets above the average of the dams of four generations, the production of the three generations in the female line being strikingly similar. High fecundity, however, was maintained throughout the four generations. High fecundity in this case was represented by 200 eggs or more in a year, though the original high foundation stock laid less than half as many eggs.

In subsequent years, interruptions due to war service interfered with the keeping of many pedigrees, but the average of the whole flock, which now numbers about 4000 fowls, has been about the same in each year.

PRODUCTION PEDIGREE OF 195 PULLETS YARD 6. THE LOWER HALF SHOWS PEDIGREE OF YARDS 1, 2, 3, 4, AND 5

- Yard 6 Pullets 1915-16 218.78 1st year 155.97 2d year
  - Sires
    - Sire D501
      - Sire 60
        - Sire
        - Dam A27 1st yr. 240 eggs 2d yr. 222 eggs 3d yr. 202 eggs 4th yr. 155 eggs
      - Dam B8 1st yr. 246 eggs 2d yr. 160 eggs 3d yr. 159 eggs 4th yr. 135 eggs
        - Sire
        - Dam 250 1st yr. 200 eggs 2d yr. 202 eggs
    - Dam C543 1st yr. 291 eggs
      - Sire
        - Sire
        - Dam 250 1st yr. 200 eggs 2d yr. 202 eggs
      - Dam 250 1st yr. 200 eggs 2d yr. 202 eggs
        - Sire
        - Dam A61 1st yr. 257 eggs 2d yr. 117 eggs
  - Dam Yards 1, 2, 3 77 hens 223.76 1st yr. 155.42 2d yr.
    - Sires 158 203 487 751
      - Sire 3 Dam A66 1st yr. 201 eggs 2d yr. 133 eggs 3d yr. 107 eggs 4th yr. 98 eggs 5th yr. 73 eggs
        - Sire
        - Dam A111 1st yr. 204 eggs 2d yr. 148 eggs
    - O. A. C. Dam Yard E 1913-14 Average 220.78 eggs
      - Sire 83
        - Sire
        - Dam 250 1st yr. 200 eggs 2d yr. 202 eggs
      - Dams Yd. C 173.66 1st yr. 199.09 2d yr.

300-egg Hens. In 1918-19 a flock of about 430 pullets (the exact number cannot be given) were trap-nested at the State Hospital, and in the flock 15 hens made records in their laying year of 300 eggs or more (see Table XLIV), the highest record being 330. The average of the 15 hens was 310.86 eggs. It is no doubt an unprecedented record to secure so many 300-egg hens in one year from a flock of that size.

Not only is the first-year record phenomenal, but the second year record is also phenomenal. In the second year one of the hens died before it laid any eggs and another died after laying 152. All the remaining 13, with one exception, laid more than 200 eggs, the highest being 264. The average of the thirteen for the second year is 224.92.

TABLE XLIV. ANNUAL AND BEST TWO-MONTHS PRODUCTION OF 300-EGG HENS—OREGON STATE HOSPITAL

Hen No.	First year	Second year	Best 2 mos. First year	Total 2 years	Dam	1st yr. eggs	Dam's dam	1st yr. eggs	Sire's dam	1st yr. eggs
237	330	216	59	546	----	------	------	------	------	------
29	323	242	61	565	285	274	16	258	C 521	303
190	323	231	60	554	----	------	------	------	------	------
264	314	205	62	519	----	------	------	------	------	------
297	313	264	58	577	----	------	------	------	------	------
444	313	206	60	519	----	------	------	------	------	------
82	310	243	59	553	----	------	------	------	------	------
38	309	------	60	--------	285	274	16	258	C 521	303
430	308	257	59	565	----	------	------	------	------	------
72	308	173	58	481	482	274	82	281	C 521	303
54	306	-D	58	--------	640	190	317	302	C 251	303
305	304	223	58	527	482	274	82	281	C 521	303
396	301	231	57	532	----	------	------	------	------	------
232	301	208	59	509	----	------	------	------	------	------
156	300	225	59	525	----	------	------	------	------	------
Average	310.86	224.92	59.13							

In the case of five of the hens the pedigree is complete. Hen No. 29, with record of 323 first year and 242 second year, is a full sister of hen 38 with record of 309 the first year and incomplete record second year. In one other case there are two full sisters, hens 72 and 305. This is significant of high breeding qualities in the dam as well as sire's dam. The sire's dam is C521 with record of 303 eggs. It is also significant that the record of the pullets exceeds the record of the dams in all cases and exceeds also the record of the sire's dam, though the difference between the sire's dam and the pullets is of no particular significance. It would appear therefore that the sire's dam in this case exercised the dominating influence.

The other ten hens are of similar breeding though their pedigrees unfortunately were lost. Probably most of them were from the same sire's dam, and it is known they were from high-record dams. Hen 54, record 306 eggs, was from a 190-egg dam, but the dam's dam laid 302, so that this hen has a grandam on both sides with record of more than 300 eggs.

BREEDING QUALITIES OR PREPOTENCY VERSUS EGG-LAYING QUALITIES AS A BASIS OF SELECTION

When the term "pedigreed high producers" is used in this bulletin it is meant to convey the meaning merely that the hen or the male in question is from a high-record dam and sire's dam. It does not mean that their breeding qualities have been tested and found good. In point of fact in the majority of cases nothing was known of the ability of the breeding males or females to transmit their qualities. It would be difficult to prove whether the increased production was due to the effect of breeding the best producers to the best producers, or of selecting among the high producers, those that were good breeders of high producers.

In other words, was the increase due to selection on the basis of egg production only, or was it due to selecting for breeding stock only those individuals that had been proved to be capable of producing high producers?

In the first years of the experiment, there was no opportunity to select by the progeny test. The only basis of selection was the egg record, and it is true, from the records of the progeny, that this method of selection was effective in all three breeds. There are indications in the records that some hens produced better layers than others; in other words, while the difference in some hens does not show by their egg records, there does appear a difference in their breeding powers, judging by the records of their progeny. It was found that there were differences in males in transmitting their laying qualities, and this fact will be discussed later. This difference, however, is not so conspicuous as to warrant any deduction that the results were due in any large measure to differences in the breeding powers of males.

The point to be emphasized in this connection, however, is that a definite increase in production was secured by breeding the best to the best; that is, by using the annual record only as a basis of selection, in other words mating high-record hens to males from high-record hens, to produce high-record progeny.

It may be asserted that it "happened" that the breeding stock used possessed the powers of transmitting high production. If so, then it may be assumed, that this is just what is likely to "happen" in all flocks where numbers are used; and that regardless of the tested breeding powers of the breeding stock, or without regard to the record of their female progeny, there is bound to be increased production if the best is bred to the best, or if the breeders are selected only because they are the best, according to their own trap-nest records. This subject will be discussed in a later bulletin in studying the records of the progeny of different males.

VARIABILITY IN HIGH AND LOW PRODUCTION

Variability in production did not decrease with increased production. In other words, the range between the highest and lowest individual records was practically the same at the end of the experiments as at the beginning. This is shown in Figs. 11, 12, and 13 of frequency distribution of hens which give the number of hens each year in groups within a range of 20 eggs. For example, in the first year, 1908-09, with a total of 92 Barred Plymouth Rock hens, in the lowest group laying between 1 to 20 eggs, there was 1 hen; in the group laying between 21 and 40 there were 6 hens; in the next group laying between 41 and 60 there were 20 hens, and in the next, laying between 61 and 80, there were 25 hens. By looking to the right in the table of Barred Rocks under the year 1912-13 of pedigreed stock it is seen that, though there were more hens in the flock, there was only one hen in those four lowest groups.

In the first year the highest number of hens was found in the group laying between 61 and 80, while in the year 1912-13 of pedigreed stock the highest number was found in the two groups ranging from 161 to 200. In the last year the highest number of hens is found in the group laying 201 to 220 eggs. As production increased there were fewer hens in the lower groups. The average hen population moved up to higher levels as a result of better breeding.

With the Leghorns the mean moved up from group 101 to 120 to 201 to 220, while in the case of the Oregons the mean moved up from group 121 to 140 to group 221 to 240. The first year of the Oregons gives the record of the first crosses and not the foundation stock of Leghorns and Rocks of the previous year.

In the last year there was apparently as great an opportunity for selection as at the beginning of the experiment.

It will be noticed also that there was a movement upward among the high groups, almost arithmetical in proportion with the lower groups. Higher levels of production were reached. Low-producing hens were being eliminated and at the same time higher-record hens obtained.

This may not mean, however, that there will be relatively fewer slacker hens or unprofitable hens as the low-producing hens are eliminated. The costs of production determine whether a hen is a slacker or not. A hen that was profitable in 1908-09 might be a slacker in 1917-18 because in the latter year the costs might have increased to such an extent that her production was not profitable. Raising the costs increases the slacker population, while lowering the costs decreases the slackers. While our experiments had to do with production, not with costs, the practical effect of increased production is increased profits by elimination of slackers.

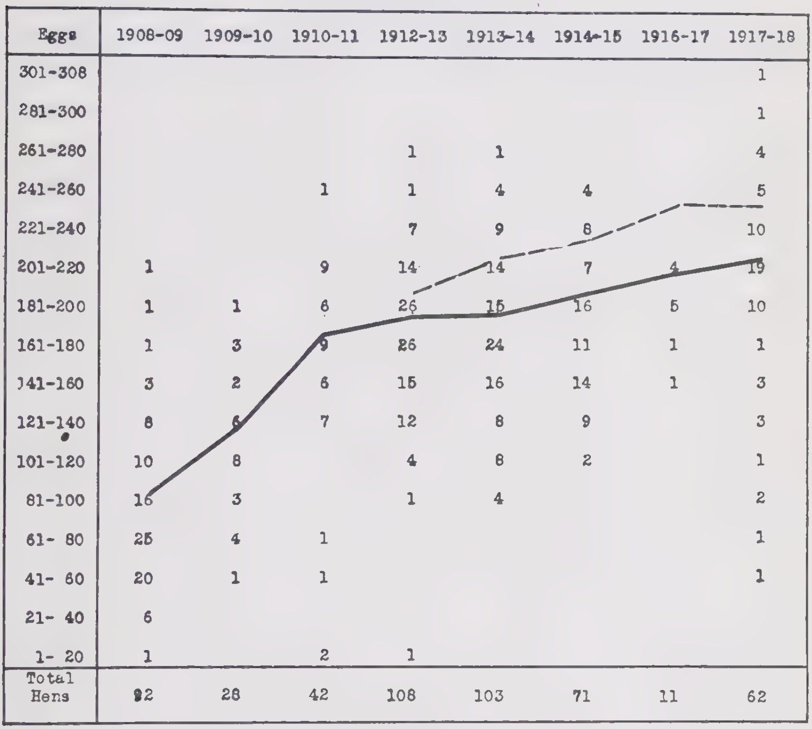
The same results are shown in the different breeds—a raising of the general average by breeding but practically the same variability in production at the beginning as at the end of the experiments.

The general average production of the hen population is shown by the heavy lines. Naturally the range will vary as the numbers in the flocks increase or decrease, but there is no mistaking the significance of these tables. While the average production of the progeny of selected high-producers is lower than the parents (dam and sire's dam) except in isolated cases already referred to, there was a progressive increase each year, individuals showing higher production than the parents in accordance with the principle or law of progression.

The actual high and low individual records of pedigreed parents and their pullets were as follows:

		1912-13		1913-14		1914-15		1915-16		1916-17		1917-18	
		High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
B. P. Rocks—	Parents	259	105	259	96	259	107	......	......	268	185	270	161
	Pullets	268	3	268	86	246	108	......	......	220	154	308	54
W. Leghorns—	Parents	240	215	......	......	267	162	......	......	302	139	302	114
	Pullets	267	119	......	......	302	100	......	......	264	63	300	23
Oregons—	Parents	257	113	226	133	303	119	303	267	......	......	303	156
	Pullets	303	123	278	58	309	77	286	156	......	......	304	123

Barred Plymouth Rocks.



Eggs	1908-09	1909-10	1910-11	1912-13	1913-14	1914-15	1916-17	1917-18
301-308								1
281-300								1
261-280				1	1			4
241-260			1	1	4	4		5
221-240				7	9	8		10
201-220	1		9	14	14	7	4	19
181-200	1	1	6	26	15	16	5	10
161-180	1	3	9	26	24	11	1	1
141-160	3	2	6	15	16	14	1	3
121-140	8	6	7	12	8	9		3
101-120	10	8		4	8	2		1
81-100	16	3		1	4			2
61- 80	25	4	1					1
41- 60	20	1	1					1
21- 40	6							
1- 20	1		2	1				
Total Hens	92	28	42	108	103	71	11	62

Fig. 11.

Figs. 11, 12, and 13. These charts show how breeding (1) increases the number of high producers, but (2) does not decrease variability; (3) how it increases average flock production, though the progeny has lower production on the average than the parents of high records selected from previous generations.

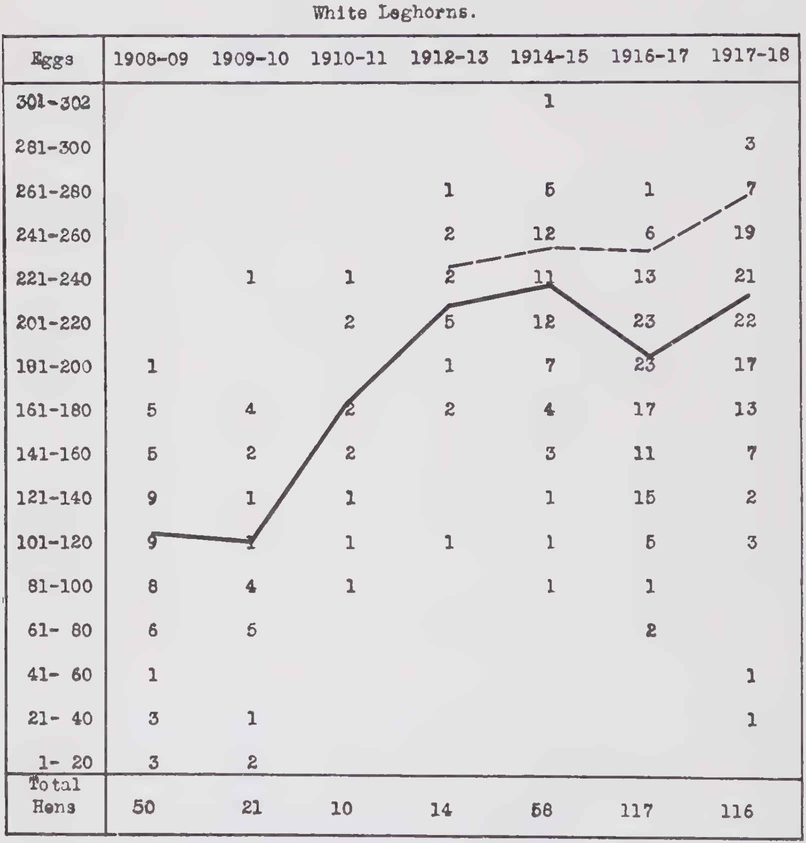
The solid line represents the average production per hen of the progeny and the dotted line the average production of the parents, or the dam and sire's dam.

In a few cases hens of low production were used as breeders, but in those cases they were mated to a sire from a high-production dam. As the dotted line in the charts (see Figs. 11, 12, 13) shows the average of the parents was high there were few low-record hens used for breeding.

PREPOTENCY, AND POOR LAYERS FROM GOOD LAYERS

While high production records of the ancestors did insure, on the average, high-producing progeny, there are many exceptions to this. Poor layers are sometimes produced by good layers.

On the other hand, we have had some cases where good layers came from poor layers. The most conspicuous example of this was the progeny of a Barred Plymouth Rock male D461-2 (Table XLV) whose dam and dam's dam and sire's dam were poor layers as shown on pedigree herewith. When he was mated to a hen with a record of 119 eggs, a pullet was produced that laid 309 eggs, the highest record at this Station. The combined record of the dam and sire's dam was 263, or 46 eggs less than the daughter.



White Leghorns.

Eggs	1908-09	1909-10	1910-11	1912-13	1914-15	1916-17	1917-18
301-302					1		
281-300							3
261-280				1	5	1	7
241-260				2	12	6	19
221-240		1	1	2	11	13	21
201-220			2	5	12	23	22
181-200	1			1	7	23	17
161-180	5	4	2	2	4	17	13
141-160	5	2	2		3	11	7
121-140	9	1	1		1	15	2
101-120	9	1	1	1	1	5	3
81-100	8	4	1		1	1	
61- 80	6	5				2	
41- 60	1						1
21- 40	3	1					1
1- 20	3	2					
Total Hens	50	21	10	14	58	117	116

Fig. 12. (See note for Fig. 11.)

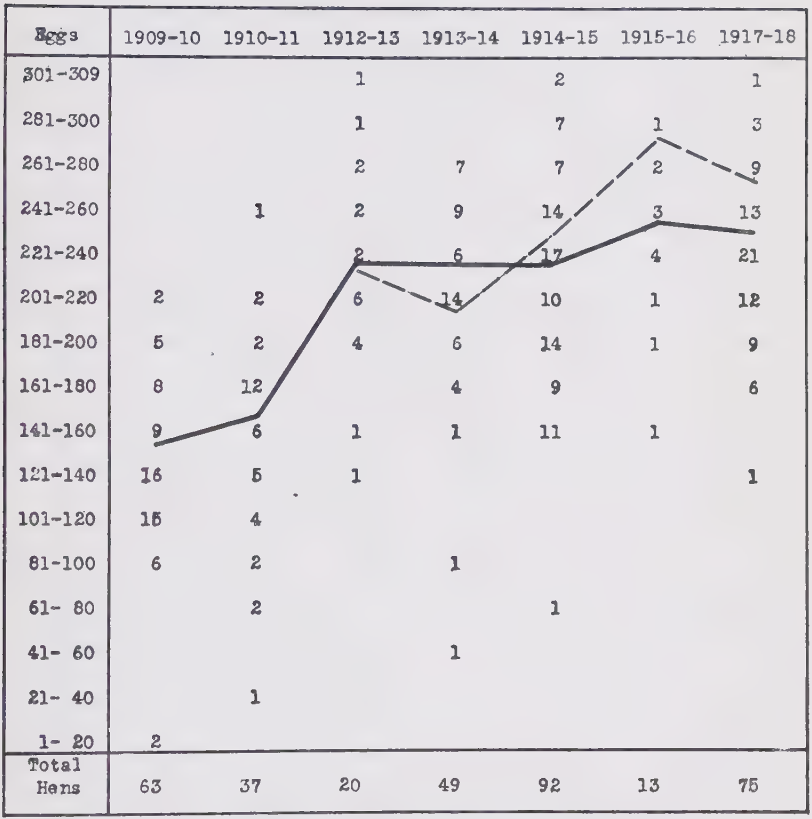
This high capacity was clearly due to the influence of the sire, because when he was mated to various other hens, the daughters were good producers, 18 of them having complete annual records, averaging

221.11 eggs. Of these, 7 were crosses, or Oregons, though the 309-egg pullet had a White Leghorn dam. The 7 daughters averaged 270.28, the average of the dams was 202.28, of the dams' dams 209.

The eleven remaining daughters were from pure Barred Plymouth Rock dams and they averaged 189.82 with high record of 260. The average of the dams was 190.09 and dams' dams 164.18.

This male apparently was strongly prepotent. Though from a line of poor producers he carried the factor of high production. His female ancestors, as far back as of record, had not high productive powers, but through the male they transmitted high fecundity to the offspring. Unfortunately after his breeding characteristics had been discovered he would not breed, and there was no progeny except in this one generation.

Oregons.



Eggs	1909-10	1910-11	1912-13	1913-14	1914-15	1915-16	1917-18
301-309			1		2		1
281-300			1		7	1	3
261-280			2	7	7	2	9
241-260		1	2	9	14	3	13
221-240			2	6	17	4	21
201-220	2	2	6	14	10	1	12
181-200	5	2	4	6	14	1	9
161-180	8	12		4	9		6
141-160	9	6	1	1	11	1	
121-140	16	5	1				1
101-120	15	4					
81-100	6	2		1			
61- 80		2			1		
41- 60				1			
21- 40		1					
1- 20	2						
Total Hens	63	37	20	49	92	13	75

Fig. 13. (See note for Fig. 11.)

It is not clear, so far as we have been able to analyze the records of this case, as to whether high prepotency appears in the later progeny of the first generation.

The daily egg record does not show high rate of laying in the dam of the 309-egg hen. The highest monthly production was 21 eggs in

May and 40 eggs as the best two-months production. The egg record of the dam of D461-2, also shows a low rate of laying, or at best a medium rate. The highest month was April, 24 eggs, and the best two months, April and May, was 43 eggs. In the second year her highest production was 22 in March. The dam's dam of the male with first-year record of 74, second year 91, third year 64, shows also low rate. In her first year, her best record was 20 eggs in March.

TABLE XLV. PEDIGREE OF BARRED ROCK MALE D 461-2 AND PRODUCTION OF DAUGHTERS AND PEDIGREE OF DAMS

- D 461-2
  - Sire 297
    - Sire
      - Sire
      - Dam 207
        1st yr. 169 eggs.
        2d yr. 127 eggs.
        3d yr. 113 eggs.
    - Dam A 94
      1st yr. 20 eggs
      2d yr. 64 eggs (D)
  - Dam H 12 N
    1st yr. 144 eggs.
    2d yr. 105 eggs.
    3d yr. 127 eggs
    - Sire
    - Dam 66
      1st yr. 74 eggs.
      2d yr. 91 eggs.
      3d yr. 64 eggs.
      4th yr. 64 eggs.

DAUGHTERS

No.	Production 1st yr.	Dam	Eggs 1st yr.	Dam's dam	Eggs 1st yr.
	Oregons				
E 138	309	C 584	119	O 34	229
E 178	299	C 503	207	A 47	205
E 156	284	C 518	226	A 47	205
E 127	274	C 503	207	A 47	205
E 114	262	C 470	211	A 47	205
E 147	241	C 503	207	A 47	205
1604	223	C 481	239	Yd. 1	......
Average	270.28		202.28		209
	Barred Rocks				
E 659	260	C 117	186	A 79	219
E 719	219	C 76	198	B 154	191
E 652	192	C 153	177	66	74
E 669	190+	C 76	198	B 154	191
E 582	188	C 76	198	B 154	191
E 619	185	C 117	186	A 79	219
E 657	183	C 153	177	66	74
E 686	178+	C 76	198	B 154	191
E 678	178	C 76	198	B 154	191
E 709	174	C 76	198	B 154	191
E 587	141	C 153	177	66	74
Average	189.82		190.09		164.18
	Both Breeds				
Average	221.11		194.83		180

Neither by the annual record, nor by rate of laying is there any proof that the ancestors of this male, so far as we have trap-nest records of them, had high laying capacity. While the ancestors of high laying capacity produced, on the average, high laying progeny, and while the more immediate parents exercised the greatest influence; in other words, while high-record pedigreed breeding stock produced high-record progeny, there are instances such as this, where the production of the progeny cannot be accounted for by the pedigree of production of the ancestors, unless it can be explained on the assumption that in a more remote ancestor or ancestors, high fecundity or high prepotency may be lost apparently and recovered in subsequent generations.

While the breeder must put his reliance largely upon pedigree of production records in selecting his breeding stock, the result secured from this male shows that there is another factor to be reckoned with, which, in the absence of a more comprehensive definition, may be called prepotency. If he wishes to make the most certain progress in increasing production by breeding, he should not be content to breed the best layers to males of the best layers, but he will breed the best breeders to the best breeders, judging from the egg records of their progeny.

Our records point out two practical conclusions of first importance that must be drawn from these experiments; first, starting with an unselected flock of layers, and using each year only those hens with high trap-nest records and males from high trap-nested hens, there is certain to be an increase in production, always providing that environmental conditions are equally favorable each year; second, by selecting the breeding stock on the basis of the egg record of the progeny, the increase may be more certain and rapid. Such males, however, as D461-2 are rare, according to our records, and only by testing the progeny of a great many sires and dams each year would a breeder be likely to find phenomenal individuals.

The pedigree of this male is given in Table XLV, together with pedigree of his daughters and record of first year's production.

RELATION OF SHORT PERIOD PRODUCTION OR RATE OF LAYING TO ANNUAL AND BIENNIAL PRODUCTION

A study of our records shows that there is a pretty accurate correlation between monthly or bimonthly production and the annual record. If it should prove that a short-period record is as good a measure of the hen's inherited capacity as the annual record, then the problem is very much simplified.

Does the rate of laying or the intensity of egg production indicate egg-laying capacity? By rate of laying is meant the relative frequency that a hen lays in a short period. If the hen lays every day without missing a day, for five or six days or more, then misses one day and begins again on another long stretch, we say that she has a high rate of laying. Another hen that lays one day and misses one, and continues this way for an indefinite period, has a low rate of laying. Our records show characteristic differences among hens and the question is, can we predict with any degree of accuracy the probable annual production of a hen from a monthly or bimonthly study of her records. Environmental factors which can not very well be controlled may interfere with the hen's laying her full annual capacity. The longer the period of the record, the greater the likelihood that some disturbing factors will interfere with production.

The records are conclusive in showing that egg production may be increased by selective breeding, based on the annual trap-nest records. The increase is such that it could hardly be ascribed to possible changes in environmental conditions of different years. The same feeding system was used throughout all the years, with some minor changes in the ration. The same housing was used. The same size of yard and flocks was maintained. In fact the conditions, on the whole, were more favorable in the first year than in later years, so far as regards housing and soil. In the first year they were new and the yards were fresh and clean, though later differences were minimized as much as possible by rotation and cultivation of yards and by disinfection of the houses.

While the annual trap-nest record of the pullets is undoubtedly the best measure of a hen's laying capacity, under favorable conditions, it is not always the best, because of the difficulty of controlling the environment. If we select for breeding a hen that has made a record of 300 eggs a year, her record would indicate that her environment was favorable. If her daughters averaged 300 eggs we might fairly conclude that they inherited the capacity of the dam, and that they were kept under favorable environment. If, however, they averaged 150 eggs it might be that they inherited low production, but on the other hand, it might be that they had equal laying capacity with the dam, but through unfavorable conditions of environment their year's record did not represent their capacity.

In a shorter period, possibly, the real laying capacity of the hen may be better shown. An attempt has been made in Tables XLVI, XLVII and XLVIII to correlate the shorter-period records, in this case the best two-month records in the year, with the annual record. Spring is the season of maximum production. It is the natural laying season, and it is reasonable to expect that the full capacity of the hen can only be secured when the conditions for production are at their best. The question then is, does the hen that lays ten or twelve months of the year, lay more eggs than the hen that lays only in the spring months? Is it true that the hen that lays heaviest in the spring months does this because she started late and discontinued early? In other words, does a moderate layer do better in the spring than a good layer? Is it true that the hen that lays heavily in the spring does so because she has been reserving her energy for spring production, and is able to beat the long-distance rival in the short period?

BEST LAYERS BEST IN ALL MONTHS

The records show conclusively that the best layers throughout the year lay the largest number of eggs in the spring or any other season. The poor layer is relatively poor in any month of the year, though she lays a larger percentage of her eggs in the spring months than the good layer.

With a correlation established between the spring months or the best two-months production of the hen, and the annual record, we can predict with some accuracy from the best two-months production what the production should be for the year. The production for the best two months affords a good basis for judging the capacity for the hen.

TABLE XLVI. SUMMARY OF ANNUAL PRODUCTION OF HENS GROUPED ACCORDING TO BEST TWO-MONTHS RECORI

BARRED PLYMOUTH ROCKS

Yard	Year	No. hens	55 up		51–55		46–50		41–45		36–40		31–35		Below 31		Annual record by years*
			No.	Average	No.	Average	No.	Average	No.	Average	No.	Average	No.	Average	No.	Average	
4 & 5	1908-09	92	....	....	....	....	7	155.71	11	107.36	10	106.50	17	84.94	47	60.13	82.67
6....	1909-10	28	....	....	....	....	....	....	5	148.40	6	136.83	8	112.50	9	92.33	117.64
15....	1910-11	42	....	....	1	204.00	5	222.00	13	182.77	12	163.83	7	141.43	4	37.25	161.78
6....	1912-13	38	1	196.00	6	218.50	11	187.82	13	171.38	5	144.80	1	89.00	1	3.00	....
7....	1912-13	37	....	....	4	210.75	15	184.80	13	175.38	3	134.00	2	134.00	....	....	174.52
8....	1912-13	33	1	196.00	5	200.60	8	185.50	10	158.50	7	164.57	1	139.00	1	107.00	
B....	1913-14	52	....	....	16	213.13	18	185.28	12	143.58	3	141.67	3	134.00	....	....	174.13
C....	1913-14	51	5	219.80	11	191.55	16	166.75	9	160.56	5	138.60	3	126.00	2	125.50	
L....	1914-15	33	2	196.50	3	182.00	12	176.42	9	177.67	5	143.40	2	124.00	....	....	180.48
P....	1914-15	38	5	215.20	6	227.17	9	193.00	13	155.08	4	166.75	1	135.00	....	....	
18....	1916-17	11	2	195.00	4	187.00	3	200.67	2	199.50	....	....	....	....	....	....	194.45
E....	1917-18	62	4	281.00	17	229.41	21	207.90	14	185.57	....	... .	4	103.25	2	148	202.40
Total........		517	20	4473	73	15435	125	23547	124	20127	60	8632	49	5406	66	4315	
Average....				223.65		211.44		188.38		162.68		143.88		110.33		65.38	158.57

*Unidentified eggs not counted.

TABLE XLVII. SUMMARY OF ANNUAL PRODUCTION OF HENS GROUPED ACCORDING TO BEST TWO-MONTHS RECORD

WHITE LEGHORNS

Yard	Year	No. hens	55 up		51–55		46–50		41–45		36–40		31–35		Below 31		Annual record by years*
			No.	Average	No.	Average	No.	Average	No.	Average	No.	Average	No.	Average	No.	Average	
4 & 5	1908-09	50	....	....	. ..	. ...	1	177.00	10	154.60	12	122.42	11	107.27	16	58.44	106.14
9....	1909-10	21	....	....	....	....	2	203.50	3	151.33	4	139.25	4	75.00	8	60.00	104.67
1....	1910-11	10	....	....	1	240.00	3	200.00	2	162.50	2	130.00	1	98.00	1	123.00	164.60
9....	1912-13	14	....	....	6	234.17	4	209.75	2	192.00	2	141.00	....	....	....	....	207.85
3....	1914-15	16	3	283.00	3	237.00	10	207.20	....	....	....	....	....	....	....	....	216.76
O....	1914-15	42	3	254.00	14	237.71	17	206.76	7	176.43	....	....	1	100.00	....	....	
P....	1916-17	49	....	....	13	211.77	24	188.25	7	160.43	5	159.20	....	....	....	....	181.50
Q....	1916-17	57	2	207.00	6	201.50	22	187.09	15	170.47	7	129.00	4	96.75	1	95.00	
15....	1916-17	11	2	233.00	6	221.17	2	206.00	1	160.00	....	....	....	....	....	....	
F....	1917-18	60	4	280.25	12	239.33	30	252.20	9	191.00	4	150.50	....	....	1	23.00	209.24
G....	1917-18	56	2	258.50	20	211.60	20	209.05	11	174.45	2	137.00	1	56.00	....	....	
Total........		386	16	4129	81	18077	135	27593	67	11422	38	5143	22	2121	27	1656	
Average....				258.06		223.17		204.39		170.48		135.34		96.41		61.33	181.71

* Unidentified eggs not added.

TABLE XLVIII. SUMMARY OF ANNUAL PRODUCTION OF HENS GROUPED ACCORDING TO BEST TWO-MONTHS RECORD
OREGONS

Yard	Year	No. hens	55 up		51–55		46–50		41–45		36–40		31–35		Below 31		Annual record by years*
			No.	Average	No.	Average	No.	Average	No.	Average	No.	Average	No.	Average	No.	Average	
7..	1909-10	33	----	--------	----	--------	----	--------	2	200.00	5	154.40	16	134.31	10	96.70	133.76
8..	1909-10	30	----	--------	----	--------	1	186.00	3	184.67	7	159.00	9	133.33	10	108.60	
1..	1910-11	37	----	--------	----	--------	5	189.20	8	170.75	9	162.67	7	139.71	8	86.37	147.16
9..	1912-13	20	4	278.25	3	245.33	9	208.67	2	196.50	1	146.00	----	--------	1	123.00	219.45
E..	1913-14	49	7	233.86	24	227.67	11	212.27	4	179.00	3	151.67	----	--------	----	--------	216.74
4..	1914-15	10	2	266.50	4	253.25	3	236.67	1	204.00	----	--------	----	--------	----	--------	217.24
5..	1914-15	10	1	200.00	4	188.00	4	216.50	1	152.00	----	--------	----	--------	----	--------	
6..	1914-15	14	2	269.50	6	221.33	5	182.40	1	177.00	----	--------	----	--------	----	--------	
J..	1914-15	58	11	276.09	16	227.87	19	209.11	7	169.86	3	176.33	1	149.00	1	77.00	
10..	1915-16	13	2	278.50	5	238.40	4	227.25	1	233.00	1	156.00	----	--------	----	--------	234.39
7..	1917-18	12	1	270.00	5	242.60	4	249.25	2	220.00	----	--------	----	--------	----	--------	227.42
H..	1917-18	63	12	244.08	32	230.56	16	208.06	2	188.50	1	123.00	----	--------	----	--------	
Totals......		349	42	10815	99	22722	81	17041	34	6201	30	4758	33	4476	30	2944	
Average..				257.50		229.52		210.38		182.38		158.60		135.64		98.13	197.58

* Unidentified eggs not added.

It may happen, however, and it is shown in our records, that a hen with high spring production does not make a high annual record due to unfavorable conditions. These conditions may be weather changes, mistakes in feeding or care, diseases, broodiness, lack of vigor, and other things. Such a hen, judged by the annual record is classed as a poor layer, when in point of fact, she has high egg-laying capacity, judged by a shorter period, and in breeding may be as valuable as the hen with the high annual record, as a breeder producing possibly as good layers as the high annual-record hen.

This may explain in part, why good layers are frequently produced by hens with low annual records.

The best two months are usually March and April, and April and May, though other months occasionally show the highest records.

VIGOR

Another factor that comes into the problem is that of vigor. It is assumed that the hen must have good vigor to stand the strain of heavy production for a year, so that any method of breeding that increases vigor should increase production. It might be a question then whether the increase in production secured by breeding from selected high producers did not primarily come from inherited vigor. That is another problem.

It has been shown by Doctor Pearl (Maine bulletin 205, Nov. 1912) that poor layers as well as good layers have more eggs or oocytes in the ovary than they have ever been known to lay, and that poor layers inherited the eggs or oocytes apparently in as great numbers as the good layers so that the inheritance of high fecundity is not a question of inheriting a great number of eggs, but rather a question of inherited capacity to lay them.

Our records show a large increase in production by breeding from high producers, and that the increase came by inheritance, but it would appear that it was rather ability to lay that was inherited than that eggs were inherited. If this ability to lay means greater vigor, is it possible to measure laying vigor by a study of our records? Vigor or lack of vigor is often evident to the eye, but not always. Very frequently the hen having all the evidences of good health and vigor does not show it in her egg record. If long-continued production indicates vigor, then it is easy to select for vigor by selecting hens with the longest productive period. Our records, however, show in many cases long production with medium low records. In these cases the records show that the hen would lay one day and miss the next or lay two days in succession and miss the third. In other words, the rate of laying was low. On the other hand, a high producer misses fewer days in the month and may lay four or five days in succession, and even many days before missing. That is a high rate of laying or intense production. Both hens are comparatively long layers. The records show another class of layers, the very poorest. This class shows a low rate of laying, and short-period production. In the first case the hen has vigor, but has not the inherited ability to lay many eggs, whatever that ability may be. But with the vigor she makes a medium good layer or medium poor layer. In the second case the hen has both high vigor and inherited ability to lay, as shown by her high rate of laying, as well as long period of high production. In the last case the hen has low vigor as well as low ability to lay, as shown by her low rate of laying and her short-period production.

Four Types of Layers. Laying hens may be divided into four distinct types, so far as their yearly trap-nest records show, as follows:

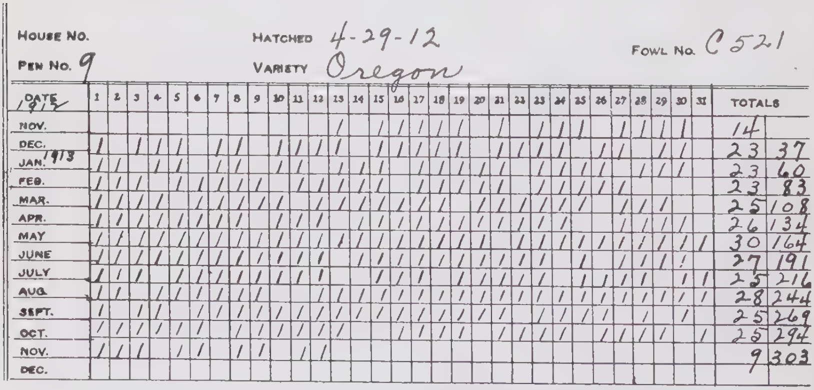
(1) The daily record of the hen of the first type shows that she starts early in the year and continues late at the latter part of the laying year. Her rate of laying is high. That is, she will miss comparatively few days. She may lay four or five or more days and miss one day, and may lay sometimes a week or two weeks without a break, and her annual record will be 200 eggs or more, depending upon how many days in succession she usually lays. This hen has high fecundity plus high vigor.

(2) The second type of hen may lay 150 eggs distributed over a comparatively long period, but her rate of laying is low. She may lay one or two days and miss one and continue in that way. She has not high capacity as shown by her low rate of production and her low best two months, but she has vigor, as shown by her steady or consistent laying. This hen has low fecundity plus vigor.

(3) The third type of hen shows a high rate of laying in the best two months but in the later months of the year she shows either a diminished rate of laying or she discontinues altogether. She may lay 150 or she may not lay 100. This hen has inherited high fecundity but lacks vigor.

(4) The fourth type of hen begins to lay late, possibly two months after the first hen started, and stops early in the year. Her laying year is short at both ends, and her rate of laying is also low. Her best two-months record is low. She has poor laying capacity and low vigor.

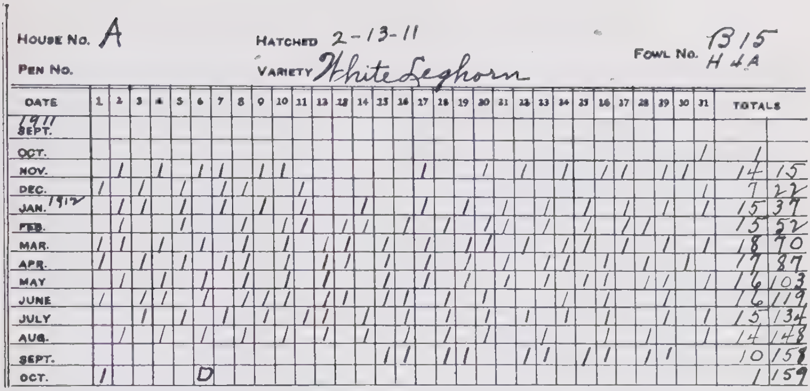
The reproduction in Figs. 14 to 17 of the actual daily records of hens illustrates the four different types.



HOUSE NO.
HATCHED 4-29-12
FOWL NO. C521
PEN NO. 9
VARIETY Oregon

DATE 1912	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
NOV.													/		/	/	/	/	/		/		/	/	/		/	/	/	/		14	
DEC.	/		/	/	/		/	/		/	/	/	/		/	/	/	/	/		/	/	/	/		/	/		/	/		23	37
JAN. 1913	/	/		/	/		/	/		/	/		/	/	/		/	/	/	/	/		/	/	/	/		/	/	/		23	60
FEB.	/	/	/		/	/	/	/	/		/	/	/	/	/		/	/	/	/	/		/	/	/	/	/					23	83
MAR.	/	/	/	/		/	/	/	/	/		/	/	/	/	/	/	/		/	/	/	/	/	/		/	/	/			25	108
APR.	/	/	/	/	/	/	/	/		/	/	/		/	/	/	/	/	/	/	/	/	/	/			/	/	/	/		26	134
MAY	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/	30	164
JUNE	/	/	/	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/		/		/	/	/	/		27	191
JULY	/	/	/		/	/	/	/	/	/	/	/			/	/	/		/	/	/	/	/		/	/	/	/		/	/	25	216
AUG.	/	/		/	/	/	/	/	/			/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	28	244
SEPT.	/		/	/		/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/		/	/	/	/		/		/		25	269
OCT.	/	/	/	/	/	/		/	/	/	/	/	/			/	/	/	/		/	/	/	/		/	/	/	/		/	25	294
NOV.	/	/	/		/	/		/	/		/	/																				9	303
DEC.																																	

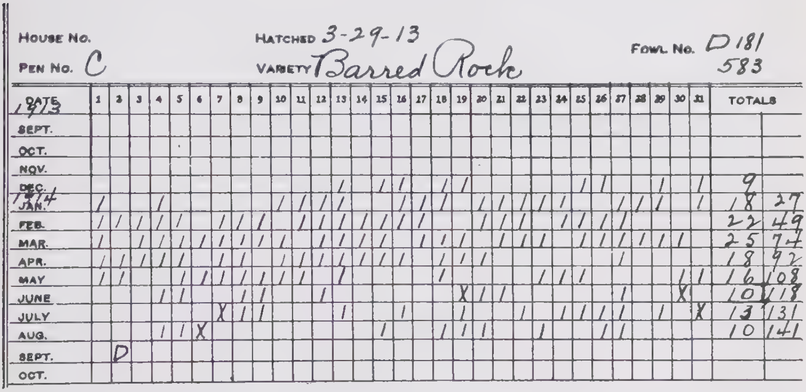
Fig. 14. Daily record of C521 showing high rate of laying through twelve months, indicating (1) inherited high laying capacity, (2) good vigor, and (3) favorable environment.



HOUSE NO. A
HATCHED 2-13-11
FOWL NO. B15 H4A
PEN NO.
VARIETY White Leghorn

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
1911 SEPT.																																	
OCT.																															/	1	
NOV.		/		/		/	/		/	/							/			/		/		/		/	/		/	/		14	15
DEC.	/		/		/		/	/			/																				/	7	22
JAN. 1912		/	/		/		/		/		/			/			/		/		/		/		/		/		/		/	15	37
FEB.		/			/			/		/	/		/	/		/		/		/	/		/		/		/	/				15	52
MAR.	/	/		/		/		/		/		/	/		/		/		/	/		/		/	/		/		/		/	18	70
APR.	/		/		/		/	/		/		/	/		/		/		/		/		/	/		/		/		/		17	87
MAY		/		/		/		/		/		/			/		/		/		/		/		/	/		/	/		/	16	103
JUNE	/		/	/		/		/	/	/		/	/		/	/		/		/				/		/			/			16	119
JULY			/		/		/		/		/	/		/		/		/		/		/		/		/			/		/	15	134
AUG.		/		/		/		/		/		/		/		/		/		/			/			/		/			/	14	148
SEPT.															/	/		/	/			/	/		/	/		/	/			10	158
OCT.	/					D																										1	159

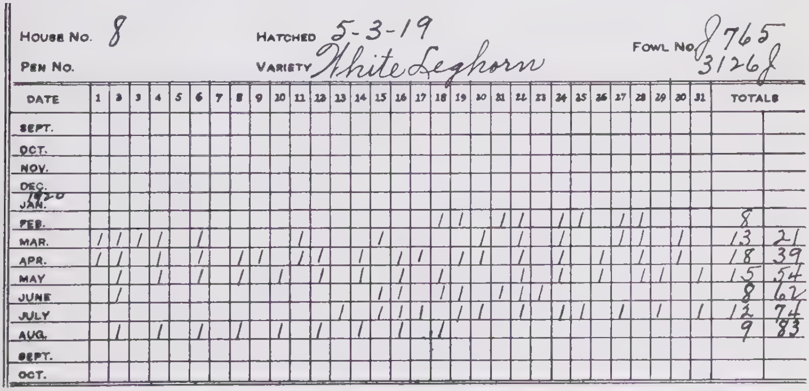
Fig. 15. Daily record of B15 showing low rate, but consistent laying throughout the year, indicating (1) poor laying capacity, (2) good vigor, (3) favorable environment. Note Figs. 18 and 19, giving record of sister and dam indicating inherited low rate of laying.



HOUSE NO.
HATCHED 3-29-13
FOWL NO. D181 583
PEN NO. C
VARIETY Barred Rock

DATE 1913	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
SEPT.																																	
OCT.																																	
NOV.																																	
DEC.													/		/	/		/	/						/	/			/		/	9	
1914 JAN.	/			/						/	/	/	/			/	/	/		/	/	/	/	/			/	/	/		/	18	27
FEB.	/	/	/	/	/		/	/	/		/	/	/	/	/	/	/			/	/	/		/	/	/	/					22	49
MAR.	/		/	/	/	/	/	/	/	/		/	/	/	/		/	/	/		/	/	/		/	/	/	/	/	/		25	74
APR.	/	/	/	/	/		/	/		/	/	/	/	/	/	/		/	/	/							/					18	92
MAY	/	/			/	/	/	/	/	/	/		/					/					/	/	/					/	/	16	108
JUNE				/	/			/	/			/							X	/	/						/			X		10	118
JULY							X	/	/				/			/			/			/		/	/	/	/		/		X	13	131
AUG.				/	/	X									/			/	/	/			/			/	/					10	141
SEPT.		D																															
OCT.																																	

Fig. 16. Daily record of D181 showing high rate of laying for short period, indicating (1) inherited good laying capacity; (2) poor vigor.



HOUSE NO. 8
HATCHED 5-3-19
FOWL NO. J765 3126J
PEN NO.
VARIETY White Leghorn

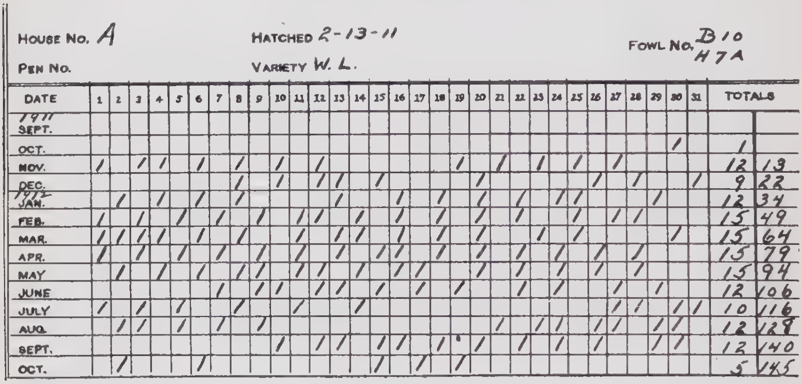
DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
SEPT.																																	
OCT.																																	
NOV.																																	
DEC.																																	
1920 JAN.																																	
FEB.																		/	/		/	/		/	/		/	/				8	
MAR.	/	/	/	/		/					/				/					/		/		/			/	/		/		13	21
APR.	/	/		/		/		/	/		/	/		/		/	/		/	/		/		/		/		/		/		18	39
MAY		/		/		/		/		/		/		/		/		/				/		/		/		/	/		/	15	54
JUNE		/													/	/		/	/		/	/	/									8	62
JULY													/		/	/	/		/	/		/		/	/		/		/		/	12	74
AUG.		/		/		/		/		/		/		/		/		/														9	83
SEPT.																																	
OCT.																																	

Fig. 17. Daily record of J765, showing low rate, late laying maturity, inconsistent laying, early quitting at end of year, indicating poor laying capacity and poor vigor.

RATE OF LAYING INHERITED

Evidence that rate of laying is inherited is furnished by the daily record of B10, sister of B15, both showing same characteristic laying as their dam 47. The records of B10 and 47 are shown in Figs. 18 and 19.

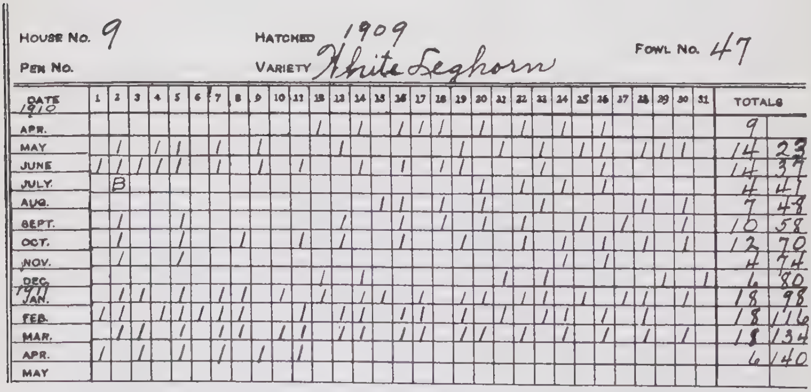
Fig. 20 shows record of hen of very high capacity inherited from ancestors, but through a break in her record due to some unfavorable environment, including molting, her record does not indicate her full capacity.



HOUSE NO. A
PEN NO.
HATCHED 2-13-11
VARIETY W. L.
FOWL NO. B10 H7A

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
1911 SEPT.																																	
OCT.																														/		1	
NOV.	/		/	/		/		/		/		/							/		/		/		/		/					12	13
DEC.								/		/		/	/		/					/						/		/			/	9	22
1912 JAN.		/		/		/		/					/			/		/		/		/		/	/				/			12	34
FEB.	/		/		/		/		/		/	/		/		/		/		/		/			/		/	/				15	49
MAR.	/	/	/	/		/		/			/		/	/		/		/		/			/		/					/		15	64
APR.	/		/		/		/		/		/		/		/	/		/		/		/		/		/		/				15	79
MAY		/		/		/		/	/		/	/		/		/	/			/		/		/		/		/				15	94
JUNE							/		/	/		/	/		/		/		/			/		/			/		/			12	106
JULY	/		/		/			/			/			/													/	/		/	/	10	116
AUG.		/	/		/		/		/												/		/	/		/	/		/	/		12	128
SEPT.										/		/	/		/	/		/		/		/		/		/			/	/		12	140
OCT.		/				/									/		/		/													5	145

Fig. 18. Daily record of B10, almost a complete duplicate of the record of her full sister B15. Poor laying capacity, but good vigor.



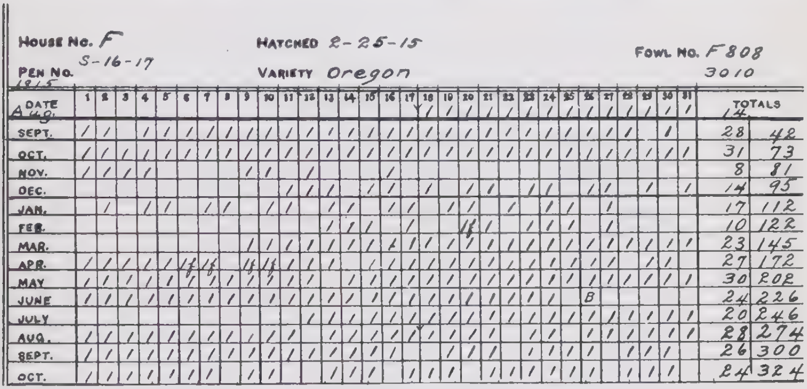
HOUSE NO. 9
PEN NO.
HATCHED 1909
VARIETY White Leghorn
FOWL NO. 47

DATE 1910	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
APR.												/		/		/	/	/		/		/		/		/						9	
MAY		/		/	/		/		/				/						/		/		/		/	/		/	/	/		14	23
JUNE	/	/	/	/	/		/		/		/			/		/		/	/				/			/						14	37
JULY		B																		/		/		/		/						4	41
AUG.															/	/		/		/			/					/		/		7	48
SEPT.		/			/								/			/		/		/		/			/		/			/		10	58
OCT.		/			/			/			/		/			/			/			/		/		/		/		/		12	70
NOV.		/			/																			/		/						4	74
DEC.												/		/							/		/						/		/	6	80
1911 JAN.		/	/		/		/	/		/		/		/	/		/		/	/		/	/		/		/	/		/		18	98
FEB.	/	/		/	/	/	/	/			/		/	/		/	/		/		/		/	/		/		/				18	116
MAR.		/	/		/		/	/		/	/		/	/		/	/		/	/		/		/		/		/		/		18	134
APR.	/		/		/		/		/		/																					6	140
MAY																																	

Fig. 19. Daily record of 47, showing same characteristic rate of laying as that of her daughters B10 and B15, indicating transmission of low rate of laying, and good vigor.

BEST TWO-MONTHS PRODUCTION AND LAYING CAPACITY

In Table XXXVI, Barred Plymouth Rocks, it is shown that from the first year to the last of the experiment there is a decided increase in the best two-months production. In other words the rate of laying, as well as the annual production, has been increased, though it will be noticed that on a percentage basis the rate of laying did not increase as much as the annual production. The fact that the best two-months production and the rate of laying increased on the average is corroborative evidence when taken in connection with the increase shown by the annual production, that the increase came by inheritance. The other fact that the best two-months production did not increase as much as the annual record, would appear to be strong evidence that the environmental conditions under which the flocks were kept for the different years were fairly well controlled. Table LXI shows that on a percentage basis there is less difference between good and poor layers in the spring months than in other months. If the percentage increase in production showed as high for the best two months as for the year, it would then appear that the environmental conditions were not under proper control, and were such that the flocks did not lay throughout the year approximately their full capacity.



HOUSE NO. F
HATCHED 2-25-15
FOWL NO. F808
PEN NO. 1815 5-16-17
VARIETY Oregon
3010

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
Aug.																		/	/	/	/	/	/	/	/	/	/	/	/	/	/	14	
SEPT.	/	/		/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/		/		28	42
OCT.	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	31	73
NOV.	/	/	/	/					/	/		/				/																8	81
DEC.											/	/	/		/	/		/		/	/		/	/		/	/		/		/	14	95
JAN.		/		/	/		/	/		/	/		/	/		/	/		/	/		/		/	/		/					17	112
FEB.													/	/	/		/			/f	/		/	/	/		/					10	122
MAR.									/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	23	145
APR.	/	/	/	/	/	/f	/f		/f	/f	/	/	/		/	/	/	/	/	/	/	/	/	/	/	/	/		/	/		27	172
MAY	/	/	/	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	30	202
JUNE	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/		B						24	226
JULY												/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	20	246
AUG.	/	/	/	/	/	/	/	/	/	/	/		/	/	/	/	/	/	/	/	/		/	/		/	/	/	/	/	/	28	274
SEPT.	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/			/	/	/		/	/	/	/		/	/	/		26	300
OCT.	/	/	/	/	/	/	/		/	/			/	/	/		/	/	/		/	/	/	/	/	/		/	/	/		24	324

Fig. 20. Daily record of F808, granddaughter of C521, showing high rate of laying, but unfavorable environmental conditions part of the year. Her high egg-laying capacity is indicated (1) by her early laying maturity, (2) high rate of laying, (3) heavy laying at the end of the year. Her rate of laying would indicate that this hen had a capacity of about 300 eggs. Her record was 262 in the first twelve months of laying. Her sire's dam laid 291, dam 254, dam's dam 303.

On the other hand, when the annual production is high, and the maximum bimonthly production, though high, shows a smaller percentage increase from low to high month than in cases where the annual production is low, it would appear evident that the conditions were favorable throughout the year.

It will be noted from the summary of the Barred Plymouth Rock for different years (Table XXXVI) that the average of the best two-months production of all years and flocks is 42.25 eggs a hen. In the first year the average of the 92 hens was 31.29 eggs a hen. In the last year the average of 62 hens was 47.19 eggs a hen. In the first year the annual production was 86.14 and in the last year 214.63. The increase in the annual flock record was 149.16 percent and in the best two months the increase was 50.8 percent. If we take the second year 1909-10 as a starting point, the increase in annual production is 77.85 percent, while the best two-months increase is 39.08 percent.

The best two months are, on the average, March and April. In case of individual hens, however, the best two months may be April and May, or May and June. The average for all the flock for best two months, as shown by the table, is 42.25 eggs a hen, while the average for March and April is 38.15 eggs a hen.

TABLE XLIX. PERCENTAGES BEST TWO-MONTHS PRODUCTION BARRED PLYMOUTH ROCKS

Year	Above 55	51-55	46-50	41-45	36-40	31-35	Below 31
1908-09........	....	....	7.6	11.96	10.87	18.48	51.09
1909-10........	....	....	....	17.86	21.43	28.57	32.14
1910-11........	....	2.38	11.9	30.95	28.57	16.67	9.52
1912-13........	1.85	13.88	31.48	33.33	13.88	3.7	1.85
1913-14........	4.85	26.21	33.01	20 39	7.77	5.83	1.94
1914-15........	9.86	12.68	29.58	30.99	14.08	2.81	....
1916-17........	18.18	36.36	27.27	18.18	....	....	....
1917-18........	6.45	27.42	33.87	22.58	6.45	3.23	....

Table XLIX shows by percentages the increase in the best two months for the different years in the case of Barred Plymouth Rocks. It is seen that in the first two years, none of the hens in the flock laid more than 50 eggs in the best two months, and only 7.6 percent of the flocks of 1908-09 laid more than 45 eggs, while better than 51 percent of them laid fewer than 30 eggs in the best two months. In the first year of the pedigreed stock 1.85 percent of them laid more than 55 eggs in the best two months, 13.88 percent laid between 50 and 55 eggs, 31.48 percent laid between 45 and 50 eggs, and only 1.85 percent of the flock laid fewer than 30 eggs in the best two months. There was the same percentage above 55 as below 30 in the last year's flock. In the rest of the years there is an increasing number in the high columns except in the last year, 1917-18. The explanation for this latter fact possibly is because this flock may have been in some respects under slightly more favorable conditions than those of the previous years. If conditions are favorable throughout the year there might be a slight decrease in the high months, if in the low months the production was unusually high. This was true of the 1917-18 flock. Their production in the low months was higher than that of the flocks of previous years.

If a good layer is not pushed, or for some other reason she does not lay her full capacity in the winter months, the presumption is that if she is in good physical condition she will lay a greater number of eggs in the spring months than she would otherwise. This does not alter the fact, however, that the poor or unselected layers in the first two years did not lay heavily in the season of maximum production, even though their winter production was also low.

There can be no other explanation of the showing made from the Barred Plymouth Rocks in this table, in connection with the record of annual production, except the fact of transmission of high fecundity.

In the case of the White Leghorns, the rate of laying is represented by 44.76 eggs a hen for the best two months for all the years, or 32.54 in the first year, and 48.16 in the last year, an increase of 48 percent, while the increase in the annual production is 98.72 percent.

If the hens are placed in different groups, according to the number of eggs they lay in the best two months, we find that there is, as in the case of the Barred Plymouth Rocks, a steady increase in the number of hens in the high groups. In the first two years of unselected or non-pedigreed stock, none of the hens laid more than fifty eggs in the best two months. Only 2 percent of them laid 46 to 50 eggs, inclusive, while 32 percent of them laid 30 eggs or less. In the first year of the pedigreed stock, 1912-13, 42.86 percent laid 51 to 55 eggs inclusive, and none laid fewer than 36 eggs. In the last three years a fair percentage of them laid above 55 eggs. Practically none of the pedigreed stock in all the years laid fewer than 31 eggs, while a large percentage of them in the unselected flock laid fewer than 31.

TABLE L. PERCENTAGES BEST TWO-MONTHS PRODUCTION
WHITE LEGHORNS

Year	Above 55	51-55	46-50	41-45	36-40	31-35	Below 31
1908-09	....	....	2.00	20.00	24.00	22.00	32.00
1909-10	....	....	9.52	14.29	19.05	19.05	38.09
1910-11	....	10.00	30.00	20.00	20.00	10.00	10.00
1912-13	....	42.86	28.57	14.28	14.28	....	....
1914-15	10.34	29.31	46.55	12.07	....	1.72	....
1916-17	3.42	21.37	41.02	19.66	10.26	3.42	0.85
1917-18	5.17	27.59	43.10	17.24	5.17	0.86	0.86

TABLE LI. PERCENTAGES BEST TWO-MONTHS PRODUCTION
OREGONS

Year	Above 55	51-55	46-50	41-45	36-40	31-35	Below 31
1909-10	....	....	1.59	7.94	19.05	39.68	31.75
1910-11	....	....	13.51	21.62	24.32	18.92	21.62
1912-13	20.00	15.00	45.00	10.00	5.00	....	5.00
1913-14	14.29	48.98	22.45	8.16	6.12	....	....
1914-15	17.39	32.61	33.69	10.87	3.26	1.09	1.09
1915-16	15.38	38.46	30.77	7.69	7.69	....	....
1917-18	17.33	49.33	26.67	5.33	1.33	....	....

In rate of laying the Oregons show an increase in best two months between the first cross and the last of 58.05 percent.

In the percentage table (LI) where the flocks of each year are grouped according to best two-months production, we find that there were no hens in the flock of non-pedigreed stock, that laid more than 50 eggs in the best two months during the first two years. Only 1.59 percent of the first generation of crosses laid more than 45 in the best two months while 39.68 percent laid between 31 and 35 inclusive and 31.75 percent laid 30 eggs or less. Practically none of the pedigreed stock laid fewer than 36 eggs as their best two-months production, while in the first year of pedigreed stock, 20 percent of the flock laid more than 55 eggs and 15 percent laid between 51 and 55 eggs inclusive. In the last year more than 60 percent of the flock laid above 50 eggs a hen in the best two months.

The same general result was secured with Barred Plymouth Rocks, White Leghorns, and Oregons; namely, an increase in the egg-laying capacity of the hen, as judged by her record in the season of maximum production when the environmental factors are most favorable for determining her full capacity. It would appear that the characteristic of high rate of laying is inherited along with high annual production.

Culling Practice. An accurate culling practice may be based upon these findings. A low record for two months shows that the hen has low capacity and will make a low annual record. If the poultryman trap-nests his flock, he may discard or market all hens that do not lay more than 35 eggs in the best two months.

Table LII has been prepared to show what would be the result if from the 517 Barred Rock hens averaging 158.57 eggs a year we had culled out all hens that laid fewer than 36 eggs in the best two-months production. Of the total, 402 laid more than 35 eggs a hen in the best two months and averaged 179.75 eggs a hen. The remainder, or 115, laid 35 eggs or less in the best two months, with an average annual record of 84.53 eggs a hen. Among these, however, there were 7 hens that laid more than the average annual production of those in the higher group that laid 36 to 40 eggs. In other words, in culling out the 115 hens there was an accuracy of 93.91 percent. This is assuming that the hen of poor laying capacity is indicated by production of 35 eggs or less in the best two months.

If the White Leghorns were culled in the same way there is an accuracy of 97.96 percent. In other words, there were 49 culls in 386 hens, and 1 of the 49 laying fewer than 36 eggs in the best two months laid more in the year than the average of the 36 to 40 group. The 49 culls averaged for the year 77.08 eggs.

TABLE LII. PRODUCTION OF HENS LAYING 36 EGGS OR MORE AND 35 EGGS OR LESS IN BEST TWO MONTHS. BARRED PLYMOUTH ROCKS

Yard	Year	No. hens above 35	Annual Average	Hens laying less than 36	Hens laying less than 36 but more than annual production of group 36-40		Per cent Accuracy	Average production of culls	Above 36 but below 143.88 annual average
					No.	Annual Average			
4 and 5	1908-09	28	119.14	64	1	153.00	98.44	66.72	22
6..........	1909-10	11	142.09	17	1	179.00	94.12	101.82	5
15..........	1910-11	31	182.45	11	2	166.50	81.82	103.55	2
6..........	1912-13	36	181.25	2	0	....	100.00	46.00	7
7..........	1912-13	35	179.91	2	1	149.00	50.00	134.00	4
8..........	1912-13	31	174.84	2	0	....	100.00	123.00	5
B..........	1913-14	49	181.49	3	2	158.00	66.67	134.00	6
C..........	1913-14	46	174.15	5	0	....	100.00	125.80	9
L..........	1914-15	31	179.74	2	0	....	100.00	124.00	5
P..........	1914-15	37	185.38	1	0	....	100.00	135.00	7
18..........	1916-17	11	194.45	0	0	....	100.00	....	0
E..........	1917-18	56	214.07	6	0	....	100.00	93.50	2
Total....		402	179.75	115	7	161.43	93.91	84.53	74

With the Oregons the percentage of accuracy was 92.06. In 349 hens, 63 were culled out; and of these 5 averaged 165.4 eggs, which was more than the average of the group laying 36 to 40 eggs. The average of the culls was 117.78 eggs.

Of the total of the three breeds, 1252 hens, there were 227 culls and only 13 of them laid above the average of the higher group.

If culling is done on the basis of egg-laying capacity and if egg-laying capacity is accurately determined by rate of laying, or the best two-months production, an accurate system of culling is indicated by the results of these experiments.

TABLE LIII. PRODUCTION OF HENS LAYING 36 EGGS OR MORE AND 35 EGGS OR LESS IN BEST TWO MONTHS. WHITE LEGHORNS.

Yard	Year	No. hens above 35	Annual Average	Hens laying less than 36	Hens laying less than 36 but more than annual production of group 36-40		Per cent Accuracy	Average production of culls	Above 36 but below 135.34 annual average
					No.	Annual Average			
4 and 5	1908-09	23	138.78	27	0	....	....	78.33	8
9..........	1909-10	9	157.56	12	0	....	....	65.00	2
1..........	1910-11	8	178.12	2	0	....	....	110.50	2
9..........	1912-13	14	207.86	0	0	....	....	....	1
3..........	1914-15	16	227.00	0	0	....	....	....	0
O..........	1914-15	41	215.61	1	0	....	....	100.00	2
P..........	1916-17	49	187.55	0	0	....	....	....	4
Q..........	1916-17	52	176.90	5	1	136.00	80.00	96.40	11
15..........	1916-17	11	215.00	0	0	....	....	....	0
F..........	1917-18	59	221.53	1	0	....	....	23.00	1
G..........	1917-18	55	202.24	1	0	....	....	56.00	2
Total Averages..........		337	196.93	49	1	136.00	97.96	77.08	33

TABLE LIV. PRODUCTION OF HENS LAYING 36 EGGS OR MORE AND 35 EGGS OR LESS IN BEST TWO MONTHS. OREGONS.

Yard	Year	No. hens above 35	Annual Average	Hens laying less than 36	Hens laying less than 36 but more than annual production of group 36-40		Per cent Accuracy	Average production of culls	Above 36 but below 158.60 group average
					No.	Annual Average			
7..........	1909-10	7	167.43	26	2	163.50	92.32	119.84	3
8..........	1909-10	11	168.45	19	1	179.00	94.74	120.32	3
1..........	1910-11	22	171.64	15	2	160.50	86.67	111.27	6
9..........	1912-13	19	224.53	1	0	....	100.00	123.00	1
E..........	1913-14	49	216.47	0	0	....	100.00	....	3
4..........	1914-15	10	246.00	0	0	....	100.00	....	0
5..........	1914-15	10	197.00	0	0	....	100.00	....	1
6..........	1914-15	14	211.14	0	0	....	100.00	....	3
J..........	1914-15	56	220.96	2	0	....	100.00	113.00	5
10..........	1915-16	13	234.38	0	0	....	100.00	....	1
7..........	1917-18	12	243.33	0	0	....	100.00	....	0
H..........	1917-18	63	224.38	0	0	....	100.00	....	1
Total Averages..........		286	215.16	63	5	165.40	92.06	117.78	27

This does not mean, however, that these 227 culls represent all the hens in the flock that made poor annual records. We have found that there is a strong correlation between the best two-months production and the annual record, but that there are exceptions to this rule. There are individual hens with high rate of laying that make a more or less poor annual record, and the probable explanation is that environmental conditions in some way interfered with their laying their full capacity during the year. In such cases the hen probably has good laying capacity but does not show it in an annual record, and she may be a good breeder of good producers.

To show, however, how many hens were left in the flock laying more than 35 eggs in the best two months, but less than the average annual production of the next higher group laying 36 to 40 eggs, a count has been made. This shows that there were 74 of these among the Barred Rocks, 33 in the Leghorns, and 27 in the Oregons, a total of 134.

If the flocks were culled by the annual trap-nest record of each hen, there would have been culled out at the end of the year 348 hens, and of these 134 were probably of good laying capacity. That is, of the 348 culled out, 134 made a low annual record, but had good laying capacity, judged by their best two months.

If, however, the flocks were trap-nested only in the season of maximum production, and all that showed a low rate of laying were culled out, according to these results the culling would show an accuracy of over 90 percent. Practically all of the hens of poor laying capacity, judged by low rate of laying, would be culled out.

Conclusions. Intensity of production, or high rate of laying, in any two months of the year is a fairly accurate measure of the hen's laying capacity, and is a valuable check on the annual record in studying the effect of selective breeding.

The best two-months record as a means of predicting what the annual record will be is accurate within a certain range. Our records show many hens with high best-two-months production, but with low annual production. This is due to other factors and not to inherited laying capacity. The hen may inherit high laying capacity or high fecundity, but other factors will prevent her making a high annual record, though in a short period or in her best two months, she may make a high record, indicating high fecundity.

The hen may inherit high fecundity, and may make a high record part of the year, including a high March and April record, but she contracts disease that reduces her production, so that her annual record does not represent her full inherited capacity. She may go broody or may go into a moult, preventing her making a high annual record, though short period production may be high. She may not inherit high vigor and at the latter part of the year break under the strain of high production, though her best two-months production may be high and represent her inherited laying capacity better than her annual record.

The writer believes that this distinction between vigor and inherited egg-laying capacity should be made in studying breeding records. It should also be considered in selecting breeding stock for breeding experiments. It may happen that in breeding from and for low producers the progeny are high producers, because the selection was made by the annual record instead of the short-period production. In selecting breeding stock, as good progeny may be secured from a hen with a record of 150 eggs as from one of 250 eggs, if in each case they show equally high production in the high production period.

The annual record of the hen does not indicate always her inherited laying capacity, and therefore, does not always indicate her breeding capacity. A hen with a poor annual record may have inherited high capacity and may be a good breeder of high producers, and the short-period production is the best explanation of this fact.

RATE OF LAYING AND CHEMICAL COMPOSITION OF THE EGG

(Preliminary Report)

In so far as ordinary food analyses are concerned, hen's eggs are of strikingly uniform quality. It might be expected, however, that the individual variations which have been shown to be extremely great in number of eggs laid, would extend in some way or in some measure to the quality of the eggs. It is known that there are some differences in the keeping quality of the eggs and considerable differences in the hatching quality as well as in quality or vigor in the chicks hatched.

The investigations reported herewith had to do with the relation between rate of laying, or the intensity of production, and the fat content of the eggs. Some important preliminary work was done in 1920 by Mary Vernon Skelton as a basis for thesis work for a Master's degree in Home Economics, on "The Fat Content of Eggs of Good and Poor Layers." The question, however, of whether the hens had high or low annual record was not involved. A good layer in this case was one with high rate of laying, as shown by her egg record for several weeks preceding the collection of eggs for analyses, and the poor layer was one of comparatively poor rate of laying. In point of fact all the hens used in this experiment were of high annual record. They were all hens that had concluded at least one year's laying and some of them several years. A record of their production for eight weeks ending April 17, 1920, together with total number of eggs laid in their first or pullet year is shown below. The eggs used for analysis were laid between April 19 and May 14.

EGG RECORD OF HENS USED IN EXPERIMENT

Poor Producers—Low Rate of Laying

Hen number	Annual record	Eight weeks record
F 281	268	25
F 281	268	25
E 285	234	25
E 229	241	32
G 529	231	28
H 66	203	31
I 196	256	31
I 198	248	30
H 200	242	33
E 260	249	35

Good Producers—High Rate of Laying

Hen number	Annual record	Eight weeks record
F 554	234	47
H 581	213	44
I 790	204	44
H 253	246	45
H 91	182	41
H 235	......	45
G 512	238	38
I 402	......	42

It will be noted that in two places the annual egg record is not given. These hens were not trap-nested in the first year, but were from high-producing strain and made a good second-year record. It will also be noted that the low-rate layers were not especially poor, but made a normal production in the eight weeks. The good producers made more than normal production.

While a sufficient number of analyses have not yet been made, the results seem to show a possible relation between rate of laying and quality of the eggs, which in this case is the fat content. The following shows the percentage of ether extract (Fat) to entire egg for the three breeds.

Breed	High rate or good producers	Low rate or poor producers
Barred Plymouth Rocks	9.9015	13.3111
Oregons	10.4624	11.8718
Leghorns	10.6819	10.6749
	Percent of ether extract to yolk:	
	%	%
Barred Plymouth Rocks	29.4332	33.7508
Oregons	28.5055	31.0077
Leghorns	27.9141	28.4035

The analyses show that the Plymouth Rock eggs had the highest percentage of fat, the Oregons second, and the Leghorns third. The difference is small and probably without significance. It may be, however, that the hen with the largest supply of body fat is best able to maintain the fat content of the egg through a prolonged and heavy laying period, assuming that the fat of the eggs comes in a measure from the reserve fat of the body of the hen.

The results, however, seem to indicate some relation between rate of laying and the fat content of the egg. The amount of fat in the egg appears to be a variable factor, depending to some extent upon the rate of laying. It is another problem whether the food has any direct relation to the fat content of the egg. Final conclusions, however, cannot be drawn until further investigations have been made.

There was no question involved in these experiments as to good and poor layers. The hens used were all good layers, or had made high annual records in the previous year or years, but during the experiment some of them were laying slowly, or at a low rate, while others were laying heavily, and they were divided into two groups on this basis.

BIMONTHLY PRODUCTION IN RELATION TO ANNUAL PRODUCTION

The best layers as shown by their annual records were the best layers throughout the year. There are individual exceptions, but by grouping all the hens together, according to annual production, and averaging the groups, the results are very conclusive. The notion that poor layers lay well or as well as the good layers in the spring season, or season of maximum production, is clearly disproved. Not only are the poor layers poor at the beginning and end of the year, but they are poor at the middle, or the favorable season of production.

For the purpose of this study all the hens have been put into five groups: The first group laying 251 to 300 plus in the first laying year, the second 201 to 250 inclusive, the third 151 to 200, the fourth 101 to 150, the fifth 1 to 100 inclusive. The production has been summarized in bimonthly periods, beginning November and ending October. The total production within these periods or months does not always equal the total annual production, because the annual-production record dates from the date of the first egg, and the first egg may be laid at different times, sometimes in October or September, while others may not start until December or January, and the end of the laying year varies accordingly. The total production for the first year, as shown in the table, is the production for the twelve months of laying, beginning with the first egg. For this tabulation we have used the calendar year to show the distribution of production by bimonthly periods.

TABLE LV. BIMONTHLY PRODUCTION PER HEN. BARRED PLYMOUTH ROCKS

Group	No. hens	Average per hen						
		Nov. Dec.	Jan. Feb.	March April	May June	July Aug.	Sept. Oct.	First year
251-300	12	22.66	41.25	53.25	48.33	44.75	43.75	269.17
201-250	113	16.62	35.99	46.91	41.71	37.05	32.49	219.15
151-200	193	7.83	28.62	42.64	37.41	31.43	22.51	176.37
101-150	109	3.34	17.64	34.39	30.41	23.67	13.06	128.28
1-100	90	1.04	6.19	20.10	15.17	14.04	4.12	66.27
Mean	517	7.97	24.31	38.16	33.25	28.31	19.99	158.57

TABLE LVI. BIMONTHLY PRODUCTION PER HEN. WHITE LEGHORNS

Group	No. hens	Average per hen						
		Nov. Dec.	Jan. Feb.	March April	May June	July Aug.	Sept. Oct.	First year
251-300	33	32.97	41.45	51.94	47.09	46.42	38.21	266.78
201-250	137	26.82	35.87	47.02	43.22	38.74	27.92	224.63
151-200	112	13.88	25.64	42.75	39.02	29.93	19.64	176.77
101-150	64	6.42	18.61	35.67	31.72	21.28	9.36	128.06
1-100	40	1.65	7.10	20.15	16.95	12.60	4.32	64.20
Mean	386	17.60	27.54	41.54	37.70	31.24	20.88	181.71

TABLE LVII. BIMONTHLY PRODUCTION PER HEN. OREGONS

Group	No. hens	Average per hen						
		Nov. Dec.	Jan. Feb.	March April	May June	July Aug.	Sept. Oct.	First year
251-300	64	28.28	41.85	52.35	50.56	45.89	41.43	269.67
201-250	118	18.37	34.06	46.77	44.46	41.27	32.85	224.53
151-200	99	13.81	27.34	40.05	36.25	30.74	22.29	176.47
101-150	52	6.48	20.80	27.96	27.26	22.11	14.42	126.52
1-100	16	3.56	16.12	20.06	12.62	12.00	6.12	72.06
Mean	349	16.45	30.79	41.86	39.23	34.93	27.46	197.58

The average bimonthly production of the Barred Plymouth Rocks is given by groups in Table LV (see also Fig. 21). Among the 517 hens involved there were 12 with records above 250 eggs in the year; 113 averaged 201 to 250; 193 averaged 151 to 200; 109 averaged 101 to 150; and 90 averaged 1 to 100. The actual average production in the laying year is shown in the last column of the table. The annual production, however, as given is not the total of the bimonthly production in the table because the annual production of all our hens is figured, as already explained, from the date of the first egg to the end of the first twelve months.

The significant point in this summary is that the highest group has the highest average in any two months in the year beginning with November and December, and that there is a gradual decrease in bimonthly production as the annual production decreases.

There is a greater difference between good and poor layers in November and December than in any other two months figured on a percentage basis. For example, the average November and December production of highest group was 22.66 eggs a hen, while the production of the lowest group was 1.04 eggs, an actual difference of 21.62 eggs a hen. In March and April when all the groups lay the best there is an actual difference in the yield between the highest and lowest group of 33.15 eggs. Figured on a percentage basis, however, the increase from the lowest to the highest or the decrease from the highest to the lowest is greater in November and December than in any other two months.

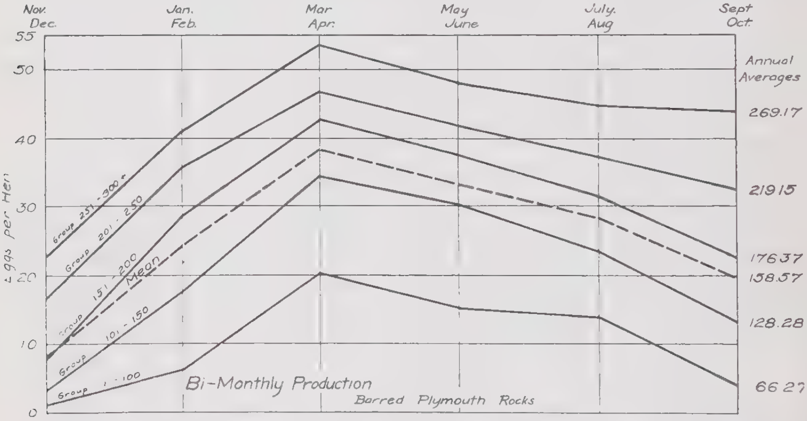


Fig. 21. Average bimonthly production of Plymouth Rock pullets, showing correlation between short-period production and annual production.

The relative values of good and poor layers are probably best shown by proportion or in ratio of production of birds in high groups to other groups. From Table LVIII it is seen that one hen in the highest group laid as many eggs in November and December as 21.79 hens in the lowest group, or 2.89 hens in the middle group. In March and April one hen in the highest group laid as many as 2.65 hens in the lowest group and 1.25 hens in middle group. In the last two months, September and October, the highest group averaged as many eggs per hen as 10.62 hens in the lowest group. Taking the annual average it required 4.06 hens or 4 times as many in the lowest group to lay as many eggs as 1 hen in the highest group. In the second lowest group, laying 100 to 150 eggs, it required 2.1 hens or double the number, to produce as many eggs in a year as the average hen in the first group averaging 250 to 300 eggs.

A summary of the bimonthly production of the White Leghorns is given in Table LVI (see also Fig. 22). In the highest group there were 33 hens that averaged 32.97 eggs a hen in November and December and

51.94 eggs in March and April. In the lowest group, laying fewer than 100 eggs, the production was only 1.65 eggs a hen in November and December and 20.15 eggs in March and April. At the end of the year or in the months of September and October the highest group averaged 38.21 eggs and the lowest 4.32 eggs.

TABLE LVIII. SHOWING PROPORTION BETWEEN PRODUCTION OF HENS IN HIGHEST GROUP AND THOSE IN EACH OTHER GROUP. BARRED PLYMOUTH ROCKS

Group	No. hens	Nov. Dec.	Jan. Feb.	March April	May June	July Aug.	Sept. Oct.	First year
251-300	12	1	1	1	1	1	1	1
201-250	113	1.36	1.15	1.14	1.16	1.20	1.35	1.23
151-200	193	2.89	1.44	1.25	1.29	1.42	1.95	1.53
101-150	109	6.78	2.34	1.55	1.59	1.89	3.35	2.10
1-100	90	21.79	6.66	2.65	3.19	3.19	10.62	4.06

There is a gradual and consistent decline in the number of eggs laid in different periods. This decline follows closely the decline in annual production. The fact stands out here that the best layers in the year are the best at any season of the year, even in March and April, the season of maximum production. While the difference in the egg yield in November and December and that of March and April between the highest group and the lowest is practically the same, the percentage difference is less in March and April than in November and December. In either period the low group could be culled out either in November and December or in March and April.

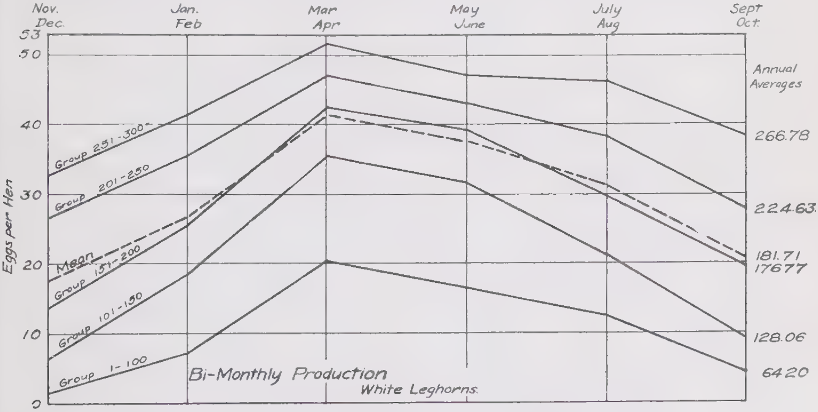


Fig. 22. Average bimonthly production of White Leghorn pullets, showing correlation between short-period production and annual production.

The relative value of hens of the different groups at different periods is better shown in Table LIX. For example, among the group of hens that laid 251 to 300 eggs in the year, one hen laid as many eggs in November and December as 19.98 hens in the lowest group averaged in the same month. In other words, 33 hens in the highest group laid 1088 eggs in November and December, while 40 hens in the low group laid only 66 eggs in the same time. So in other groups. Hen values

TABLE LIX. SHOWING PROPORTION BETWEEN PRODUCTION OF HENS IN HIGHEST GROUP AND THOSE IN EACH OTHER GROUP. WHITE LEGHORNS

Group	No. hens	Nov. Dec.	Jan. Feb.	March April	May June	July Aug.	Sept. Oct.	First year
251-300+	33	1	1	1	1	1	1	1
201-250	137	1.23	1.15	1.10	1.09	1.20	1.37	1.19
151-200	112	2.38	1.62	1.21	1.21	1.55	1.95	1.51
101-150	64	5.13	2.23	1.46	1.48	2.18	4.08	2.08
1-100	40	19.98	5.84	2.58	2.78	3.68	8.84	4.16

decrease in bimonthly periods especially in November and December as their annual production decreases.

The same thing is true of the Leghorns as of the other breeds. In this regard, there is less difference in hen values in the months of March and April, the season of highest production, than in any other period. In these two months one hen in the highest group equaled 2.58 hens in the lowest group.

In the total for the year for Leghorns, one hen in the highest group equaled 4.16 hens in the lowest group. In other words, each of four and a fraction hens in the lowest class took up as much room and ate about as much feed in the year as one hen did in the high group. Knowing the production of the hens in March and April an intelligent culling may be done.

In the case of the Oregons (Table LVII; see also Fig. 23), there were 64 hens in the highest group; 118 in the second; 99 in the third; 52 in the fourth; and 16 in the fifth or a total of 349 hens. Sixty-four hens in the highest group averaged 28 eggs in the bimonthly period of November and December, and 52.35 eggs in March and April. In the lowest group sixteen hens averaged 3.56 eggs in November and December and 20.06 eggs in March and April, and so on.

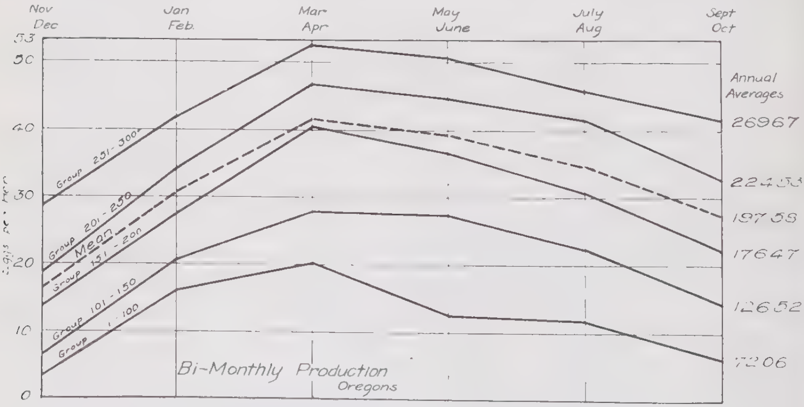


Fig. 23. Average bimonthly production of Oregons, showing correlation between short-period production and annual production.

The highest group laid in November and December 28.28; 24.72 eggs more than the lowest group, or some seven hundred percent more. In March and April the highest group laid 32.29 eggs more than the lowest, or some 160 percent more. The actual difference in eggs laid was greater in the high months than the low months, but the percentage difference was greater in the low months.

Computing the difference in another way, as in Table LX, one hen in the highest group laid as many eggs in November and December as did 7.94 hens in the lowest group, while in March and April 2.61 hens in the lowest group laid as many as one hen in the highest. The same thing is true in all of the groups and all the months.

TABLE LX. SHOWING PROPORTION BETWEEN PRODUCTION OF HENS IN HIGHEST GROUP AND THOSE IN EACH OTHER GROUP. OREGONS

Group	No. hens	Nov. Dec.	Jan. Feb.	March April	May June	July Aug.	Sept. Oct.	First year
251-300	64	1	1	1	1	1	1	1
201-250	118	1.54	1.23	1.12	1.14	1.11	1.26	1.20
151-200	99	2.04	1.53	1.31	1.39	1.49	1.86	1.53
101-150	52	4.36	2.01	1.87	1.85	2.08	2.87	2.13
1-100	16	7.94	2.59	2.61	4.01	3.82	6.77	3.74

In the discussion of short-period production as a measure of laying capacity, it was shown that as the maximum best-two-months production increased, the annual production increased. In this study we see that as the annual production increased, the best two-months production increased. While the greatest increase in production has come in the low months of the year, or at the beginning and end of the year, there is also a considerable increase in production in the favorable months.

Though the production draws closer together in the spring months, than at the beginning and end of the year, there is in these two months a decided difference between good and poor layers. In other words, there is a strong correlation between laying capacity, as determined by the annual record, and March and April production.

The difference in production in November and December, however, is not always a question of rate of laying. Where the records show that a hen laid only 3.66 eggs as an average in November and December, it does not mean that the production was spread over the two-months period. It means that, while the rate of laying was low, the pullets did not start as early as the high group. But in March and April when the hens were all laying, and laying throughout the full two-months period, the difference in production in the group is a difference in rate of laying. In the first two months, there is a question of laying maturity involved as well as rate of laying, while in March and April, the only question is rate of laying.

Bimonthly Percentage Production. In Tables LXI, LXII, LXIII is shown in percentage the bimonthly production of Barred Plymouth Rocks, White Leghorns, and Oregons, arranged in groups according to annual production. This is based on the possible hen production of an egg a day. It will be understood that these bimonthly percentages would vary if artificial lights were used on the flocks. The production would be higher in the fall and early winter months with lights and probably less in the spring months. But under natural conditions of lighting and care, the table affords a basis for estimating fairly accurately the annual production of a flock. In the absence of trap-nest records, the owner of a flock under good care may know, within a reasonable range, from the flock record in any two months, preferably in the spring months of best production, what the production of the flock will be in the year. If he has a good laying strain and they do not come up to the production shown in the table in any months he will know that he is not giving them proper care.

TABLE LXI. PERCENTAGE BIMONTHLY PRODUCTION. BARRED PLYMOUTH ROCKS

Group	No. Hens	Nov. Dec.	Jan. Feb.	March April	May June	July Aug.	Sept. Oct	First year	Annual Prod.
251-300	12	37.16	69.92	87.29	79.23	72.17	71.72	73.74	269.17
201-250	113	27.24	61.00	76.90	68.37	59.76	53.27	60.04	219.15
151-200	193	12.83	48.51	69.88	61.32	50.69	36.89	48.32	176.37
101-150	109	5.47	29.90	56.38	49.85	38.18	21.40	35.14	128.28
1-100	90	1.71	10.49	32.95	24.86	22.65	6.75	18.16	66.27

TABLE LXII. PERCENTAGE BIMONTHLY PRODUCTION. WHITE LEGHORNS

Group	No. hens	Nov. Dec.	Jan. Feb.	March April	May June	July Aug.	Sept. Oct.	First year	Annual Prod..
251-300	33	54.05	70.26	85.19	77.19	74.88	62.64	73.09	266.78
201-250	137	43.96	60.79	77.09	70.85	62.48	45.78	61.54	224.63
151-200	112	22.76	43.46	70.08	63.96	48.27	32.20	48.43	176.77
101-150	64	10.52	31.54	58.48	51.97	34.32	15.34	35.09	128.06
1-100	40	2.71	12.03	33.03	27.79	20.32	7.09	17.59	64.20

TABLE LXIII. PERCENTAGE BIMONTHLY PRODUCTION. OREGONS

Group	No. hens	Nov. Dec.	Jan. Feb.	March April	May June	July Aug.	Sept. Oct.	First year	Annual Prod.
251-300	64	46.36	70.95	85.83	82.89	74.02	67.93	73.88	269.67
201-250	118	30.12	57.73	76.67	72.89	66.57	53.86	61.52	224.53
151-200	99	22.65	46.34	65.66	59.43	49.58	36.55	48.35	176.47
101-150	52	10.62	35.27	45.84	44.70	35.67	23.64	34.66	126.52
1-100	16	5.84	27.33	32.89	20.69	19.35	10.04	19.74	72.06

If, for example, his flock is laying about 86 percent in March and April it has a capacity of more than 250 eggs a hen, and if given good care he may expect a production in the year of more than 250 eggs a hen, though there may be no flocks of large size that would average that number of eggs.

In the experimental flocks the March and April production of hens laying above 250 eggs, was as follows:

	March and April %	Annual eggs
Barred Plymouth Rocks	87.29	269.17
White Leghorns	85.19	266.78
Oregons	85.83	269.67

If the production is 32 to 33 percent in March and April he should expect a production of about 70 eggs a hen in the year. If the production in July and August is about 50 percent he can be assured of a production of about 176 eggs.

The greatest uniformity in the three breeds is in March and April, indicating that this is the best period for estimating the annual production of the flock. A 60-percent production in March and April indicates a satisfactory egg yield, while a production above 70 percent indicates a production above 200 eggs a hen.

Percentage Deviation from the Mean. In Tables LXIV, LXV, and LXVI, is given by groups the percentage deviation from the mean bimonthly production. The mean production is shown in eggs per hen, and the deviation in percentage in bimonthly periods is shown for the different groups. In the case of the Barred Plymouth Rocks, for example, the mean for November and December is 7.97 eggs per hen. In the highest group the production is 184.32 percent above the mean. In the second group it is 108.53 percent above the mean; in the third group it is 1.76 below the mean, while in the lowest group it is 86.95 percent below the mean. The plus sign before the number indicates above the mean; the minus sign indicates below the mean.

TABLE LXIV. PERCENTAGE DEVIATION FROM THE MEAN. BARRED PLYMOUTH ROCKS

Group	No. hens	Bimonthly production						
		Nov. Dec.	Jan. Feb.	Mar. Apr.	May June	July Aug.	Sept. Oct.	First year
Mean........	......	7.97	24.31	38.16	33.25	28.31	19.99	158.57
251–300....	12	+184.32	+69.68	+39.54	+45.35	+58.07	+118.86	+69.75
201–250....	113	+108.53	+48.05	+22.93	+25.44	+30.87	+62.53	+38.20
151–200....	193	—1.76	+17.73	+11.74	+12.51	+11.02	+12.60	+11.23
101–150....	109	—58.09	—27.44	—9.88	—8.54	—16.39	—34.67	—19.10
1–100....	90	—86.95	—74.54	—47.33	—54.38	—50.41	—79.39	—58.21

TABLE LXV. PERCENTAGE DEVIATION FROM MEAN. WHITE LEGHORNS

Group	No. hens	Bimonthly production						
		Nov. Dec.	Jan. Feb.	Mar. Apr.	May June	July Aug.	Sept. Oct.	First year
Mean........	......	17.60	27.54	41.54	37.70	31.24	20.88	181.71
251–300+	33	+87.33	+50.51	+25.05	+24.91	+48.59	+83.00	+46.82
201–250....	137	+52.39	+30.25	+13.20	+14.64	+24.01	+33.72	+23.62
151–200....	112	—21.14	—6.90	+2.91	+3.50	—4.19	—5.94	—2.72
101–150....	64	—63.52	—32.42	—14.14	—15.86	—31.88	—55.17	—29.53
1–100....	40	—90.63	—74.22	—51.53	—55.04	—59.67	—79.31	—64.67

TABLE LXVI. PERCENTAGE DEVIATION FROM MEAN. OREGONS

Group	No. hens	Bimonthly production						
		Nov. Dec.	Jan. Feb.	Mar. Apr.	May June	July Aug.	Sept. Oct.	First year
Mean.......	......	16.45	30.79	41.86	39.23	34.93	27.46	197.58
251–300....	64	+71.92	+35.92	+25.06	+28.88	+31.38	+50.88	+36.50
201–250....	118	+11.68	+10.62	+11.73	+13.33	+18.15	+19.63	+13.66
151–200....	99	—16.05	—11.21	—4.33	—7.59	—11.99	—18.83	—10.67
101–150....	52	—60.67	—32.45	—33.21	—30.51	—36.70	—47.48	—35.96
1–100....	16	—78.36	—47.65	—69.85	—67.83	—65.64	—77.71	—63.52

In March and April the mean is 38.16 eggs for Barred Rocks, while in the highest group the production is 39.54 percent above the mean. In the lowest group it is 47.33 percent below the mean. In the case of the Oregons, the mean was 16.45 eggs a hen in November and December, while the highest group laid 71.92 percent more than the mean, and the lowest group 78.36 less than the mean. In March and April the mean is 41.86 eggs a hen, while the highest group laid 25.06 percent more than the mean and the lowest 69.85 less than the mean.

The significance of this tabulation is that while the difference in the number of eggs laid is greater in March and April than in November and December, between the highest and lowest group the percentage difference is less in March and April than in November and December. There is not as wide a gap between the high and low groups in March and April when the difference is figured in percentage above and below the mean.

Conclusions. To summarize some of the results: When a flock averages high in November and December, or say 20 eggs a hen, which is the average of the three breeds for the group laying 201 to 250, we can expect a yield of more than 200 eggs in a year. Judging from the average of the highest group in the three breeds, a production of 27.75 eggs in November and December would indicate an annual production of 251 to 300 plus. When they lay fewer than 4 eggs in November and December, we may expect a yield of fewer than 100 a year. The intermediate groups show corresponding results.

The hens showing the lowest production in November and December, not only show the lowest through all the months, but when the year's total is figured up, it required 3.74 hens in the lowest group to lay as many in the year as one hen in the high group. In March and April one hen in the high group was equal to 2.61 hens in the lowest group. This indicates that culling may be fairly accurately done in March and April as well as November and December.

WINTER PRODUCTION AND ANNUAL PRODUCTION

In the production of the first quarter of the laying year referred to as winter production, the results show very conclusively that low production in these months, means low production for the rest of the year. High production in the winter months means high production for the rest of the year. Selective culling may be profitably done on the basis of first three months production.

The average results for the different years are given below.

Breed	No. of hens	Winter production to Jan. 31	Rest of year	Annual production
Barred Plymouth Rocks	517	19.79	138.78	158.57
Leghorns	386	35.44	146.27	181.71
Oregons	349	37.02	160.57	197.58

(Unidentified or floor eggs are not included.)

When the hens are grouped according to annual production and breed, it is shown that the best layers in the first quarter are the best in the rest of the year. For example, in the table for Barred Plymouth Rocks, the hens laying between 250 and 300 averaged 44.25 eggs a hen to January 31, and 224.92 in the rest of the year. The poor group laying from 1 to 100 averaged 3.17 eggs to January 31, and 63.08 in the rest of the year.

The same results are secured with Leghorns and Oregons, as shown in Table LXVII.

The characteristics of the good layers as shown by this tabulation, are good fall and early winter production, with good production throughout the rest of the year, including good production in the late summer and early fall. In other words, by breeding the length of the laying period is extended, both at the beginning and end of the laying year.

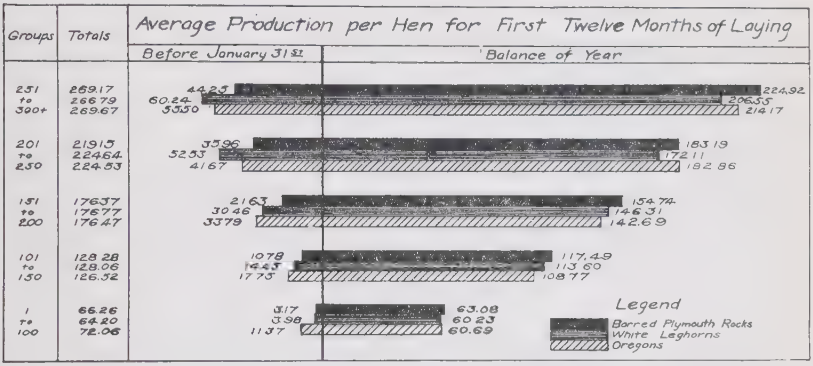


Fig. 24. Hens grouped according to production, showing correlation between fall and winter production and the remainder of the year.

CORRELATION BETWEEN THE PRODUCTION OF THE FIRST YEAR AND THAT OF THE SECOND AND SUBSEQUENT YEARS

The problems discussed so far in this bulletin have had reference only to the pullet year or first year's production. The conclusions drawn are based on those records. It is of practical importance to know whether high fecundity is inherited in the second and subsequent years. A profitable hen must be profitable for more than one year. If a hen produces well in her first year, will she produce well in subsequent years, or is it true that the more she lays in her first year, the fewer she will lay in subsequent years? Again, it is highly important for profitable egg production, that the production period of the hen, or the profitable laying life of the hen, be increased.

It was the practice each year in our experiments to retain the best layers in the first year for the second year, and the best of these again for the third and subsequent years. A few of the best layers have reached nine years of age with continuous trap-nest records. Some poor layers in the first year were also retained in second and subsequent years.

The trap-nest record begins when the hen first begins to lay, and the first year dates from that time. The second year begins at the end of the first twelve months of laying, and so on for subsequent years.

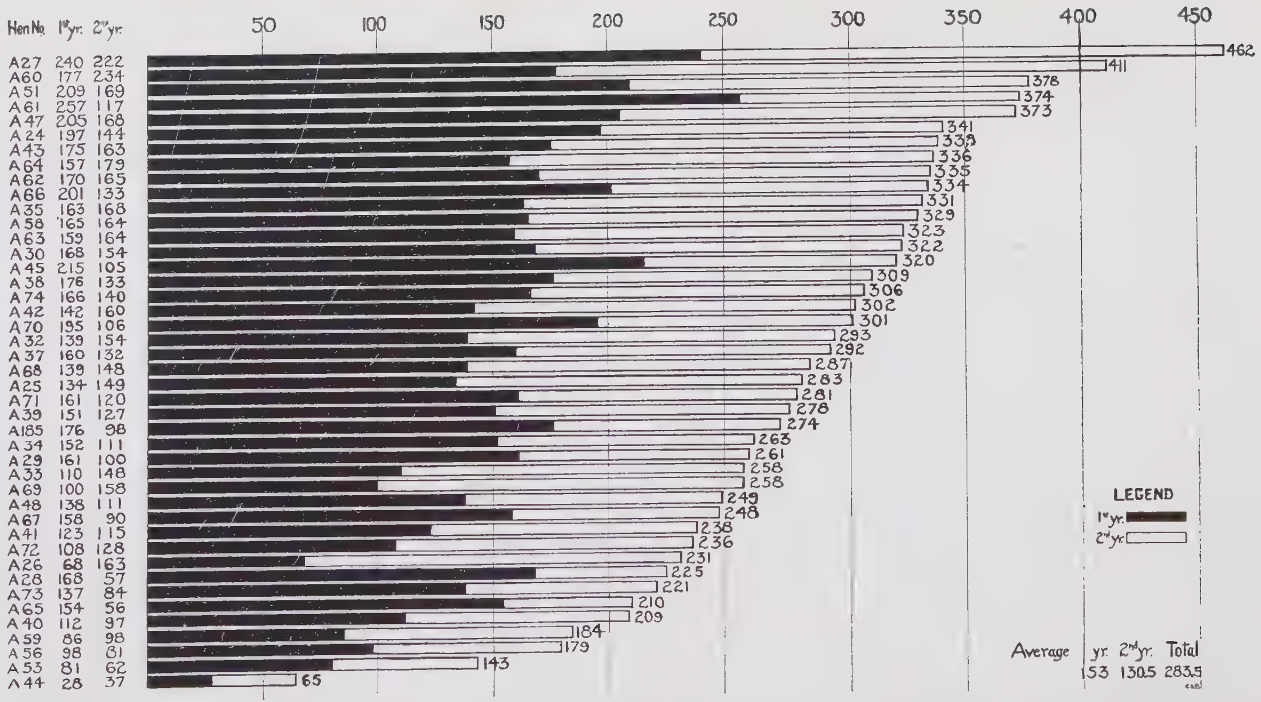


Fig. 25. Graph representing two years' trap-nest records of a pen of forty-three Leghorns and first crosses (White Leghorns and Barred Plymouth Rocks) grouped according to two years' egg production. The first and second year's production is given at the left of the chart and the total at the end of the lines on the right. This graph shows that the best layers in the first year, represented by the blank lines, are on the average the best in two years.

The results show clearly: (1) The first year is on the average the most productive or profitable year in the life of the hen. (2) The best layers in the first year are, on the average, the best in the second and subsequent years. In other words, there is a clear correlation between the production of the first year and the second and subsequent years. (3) The decrease in production from the first to the second and subsequent years is greater in the case of high producers than low first-year producers. But the second year's production of good producers is better than that of the poor producers. (4) The very poorest producers in the first year, on the average, lay better in the second year than the first year.

Averaging all the hens with two-year complete records for the different years the production is as follows:

Breed	No. of hens	1st Yr.	2d Yr.	Decrease	Percent decrease
Barred Plymouth Rocks	157	178.77	128.70	50.07	28.01
Leghorns	185	209.16	163.65	45.51	21.76
Oregons	219	200.49	161.95	38.54	19.22

This shows a considerable decrease from first to second year in all three breeds. It is understood that the hens represented in the above tabulation are of good laying strains, but there was a wide range in production of individual hens. As shown in other tables, this variation has extended from less than one hundred eggs to three hundred eggs a hen.

Computations have also been made for hens with three-year records. Their averages are as follows:

Breed	No. of hens	1st Yr.	2d Yr.	3d Yr.	Decrease 1st.-3d	Percent decrease
Barred Plymouth Rocks	35	225.89	158.20	124.20	101.69	45.02
Leghorns	96	227.58	174.59	157.24	70.34	30.91
Oregons	74	231.01	189.78	158.96	72.05	31.19

It is seen that the decrease continues from the second to the third year, though it is not quite as much in the third year as in the second. In the case of the Barred Plymouth Rocks, there is a decrease of over 100 eggs, or 45.02 percent, from first to the third year. The decrease for the Leghorns and Oregons is 70.34 and 72.05 eggs a hen. It will be remembered that the hens represented here are all heavy producers in the first year.

The Barred Plymouth Rocks decreased more rapidly in the second year and third year than the Leghorns and Oregons. The Leghorns and Oregons showed about the same decrease. Whether this is a breed or a strain difference is not clear, but it would appear from these experiments that the heavier breeds do not maintain profitable production for as many years as the lighter breeds.

To learn whether good layers and poor layers show the same percentage decrease each year, all the hens with two-year and three-year records have been grouped according to production in the first year.

The grouping of the Barred Plymouth Rocks (Table LXVIII) for the first and second years' production shows that the hens that laid 250 to 300-plus eggs in the year, averaging 266.43, averaged in the second year 164.28 eggs, a decrease of 102.15 eggs, or a percentage decrease of 38.34.

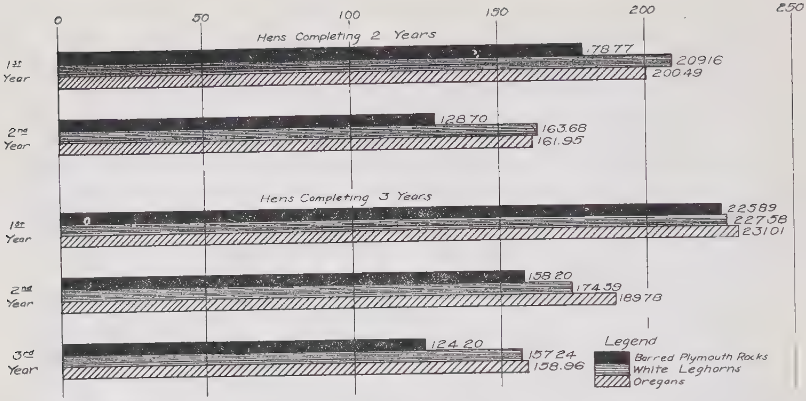


Fig. 26. Average production per hen of Barred Plymouth Rocks, White Leghorns, and Oregons, showing correlation between first and second years' production of the same hens, and first, second, and third years' production of the same hens.

While the decrease is greatest in the highest group the second year's production is highest in the highest group. In the lowest group laying one hundred eggs or less, and averaging 72.21 eggs, the average for the second year was 77.78, or an increase of 5.57 eggs a hen, or a percentage increase of 7.71.

TABLE LXVII. SUMMARY

Groups	No. of hens	Average production per hen*		
		Through January	Rest of year	Annual
Barred Plymouth Rocks				
251 to 300+	12	44.25	224.92	269.17
201 to 250	113	35.96	183.19	219.15
151 to 200	193	21.63	154.74	176.37
101 to 150	109	10.78	117.49	128.28
1 to 100	90	3.17	63.08	66.26
Average		19.79	138.78	158.57
White Leghorns				
251 to 300+	33	60.24	206.55	266.79
201 to 250	137	52.53	172.11	224.64
151 to 200	112	30.46	146.31	176.77
101 to 150	64	14.45	113.60	128.06
1 to 100	40	3.98	60.23	64.20
Average		35.44	146.27	181.71
Oregons				
251 to 300+	64	55.50	214.17	269.67
201 to 250	118	41.67	182.86	224.53
151 to 200	99	33.79	142.69	176.47
101 to 150	52	17.75	108.77	126.52
1 to 100	16	11.37	60.69	72.06
Average		37.02	160.57	197.58

*Unidentified or "floor" eggs not counted.

The same law of diminishing returns holds true with Leghorns and Oregons, that the higher the first year's production the greater the decrease in the second, but the second year's record of the highest group is better than the second year's record of the lower groups. If, therefore, high fecundity is inherited in the first year, it is inherited in the second. In Tables LXXI, LXXII, and LXXIII, showing first, second, and third years' records of hens completing three years, it will be noted that there is a decrease in all groups from the second year to the third, with one exception, that of the lowest group of Oregons. As it happened that there was only one hen in that "group," no significance can be attached to this case.

TABLE LXVIII. RATE OF DECREASE IN PRODUCTION—2 YEARS SUMMARY. BARRED PLYMOUTH ROCKS

Groups	No. hens	Average 1st year	Average 2d year	Decrease	Percent decrease
251 to 300+	7	266.43	164.28	102.15	38.34
201 to 250	69	221.36	144.07	77.29	34.92
151 to 200	36	180.11	134.05	46.06	25.58
101 to 150	22	126.54	109.09	17.45	13.79
1 to 100	23	72.21	77.78	−5.57	−7.71
Average	157	178.77	128.70	50.07	28.01

TABLE LXIX. RATE OF DECREASE IN PRODUCTION—2 YEARS SUMMARY. WHITE LEGHORNS

Groups	No. hens	Average 1st year	Average 2d year	Decrease	Percent decrease
251 to 300	27	266.81	169.00	97.81	36.66
201 to 250	96	227.57	169.54	58.03	25.94
151 to 200	39	180.25	165.46	14.79	8.20
101 to 150	19	127.31	136.84	−9.53	−7.49
1 to 100	4	94.00	97.25	−3.25	−3.46
Average	185	209.16	163.68	45.48	21.74

TABLE LXX. RATE OF DECREASE IN PRODUCTION—2 YEARS SUMMARY. OREGONS

Groups	No. hens	Average 1st year	Average 2d year	Decrease	Percent decrease
251 to 300+	51	268.27	188.45	79.82	29.76
201 to 250	73	223.93	179.01	44.92	20.06
151 to 200	49	173.89	146.59	27.30	15.69
101 to 150	37	125.02	126.46	−1.44	−1.15
1 to 100	9	81.33	102.88	−21.55	−27.12
Average	219	200.49	161.95	38.54	19.22

It will also be noted that the decrease among the different groups from the second year to the third year is not as consistent as from the first to the second. This would be expected from the relatively small number of hens with complete three-year record. From the average of the three breeds, however, the decrease is greatest from second to third year among the higher group of layers, but the decrease in the third year is much less than in the second year.

The grouping given in these tables includes hens of different yards in the different years with records for two and three years. The record shows the same general decrease in different yards of different years. The production of the first year's stock, 1908-09, does not show much decrease in the second year, but this agrees with the result of all the years, that the low-first-year hens do not show as much decrease as the

TABLE LXXI. SUMMARY OF RATE OF DECREASE IN PRODUCTION. BARRED PLYMOUTH ROCKS

Group	No. hens	Average 1st year	Average 2d year	Decrease from 1st year	Percent decrease from 1st year	Average 3d year	Decrease from 1st year	Percent decrease from 1st year	Decrease from 2d year	Percent decrease from 2d year
251 to 300+	6	269.00	182.67	86.33	32.09	157.00	112.00	41.64	25.67	14.05
201 to 250	25	223.20	153.20	70.00	31.36	119.92	103.28	46.27	33.28	21.72
151 to 200	4	178.00	151.50	26.50	14.89	141.50	36.50	20.51	10.00	6.61
Average	35	225.89	158.20	67.69	29.97	124.20	101.69	45.02	34.00	21.49

TABLE LXXII. SUMMARY OF RATE OF DECREASE IN PRODUCTION. WHITE LEGHORNS

Group	No. hens	Average 1st year	Average 2d year	Decrease from 1st year	Percent decrease from 1st year	Average 3d year	Decrease from 1st year	Percent decrease from 1st year	Decrease from 2d year	Percent decrease from 2d year
251 to 300+	19	266.32	171.79	94.53	35.50	148.74	117.58	44.15	54.21	31.56
201 to 250	60	229.27	175.12	54.15	23.62	161.33	67.94	29.63	13.79	7.87
151 to 200	15	185.80	181.40	4.40	00.24	155.60	30.20	1.63	25.80	14.19
101 to 150	2	122.50	134.50	–12.00	–8.92	127.50	–5.00	–3.92	7.00	5.20
Average	96	227.58	174.59	52.99	23.28	157.24	70.34	30.91	17.35	9.94

TABLE LXXIII. SUMMARY OF RATE OF DECREASE IN PRODUCTION. OREGONS

Group	No. hens	Average 1st year	Average 2d year	Decrease from 1st year	Percent decrease from 1st year	Average 3d year	Decrease from 1st year	Percent decrease from 1st year	Decrease from 2d year	Percent decrease from 2d year
251 to 300+	31	270.68	196.48	74.20	27.41	170.77	99.91	36.91	25.71	13.08
201 to 250	28	231.36	198.32	33.04	14.28	153.57	77.79	32.76	44.75	22.56
151 to 200	8	175.38	184.75	–9.37	–5.07	165.13	10.25	5.84	19.62	10.62
101 to 150	6	132.50	147.50	–15.00	–11.32	132.16	00.34	00.26	15.34	10.40
1 to 100	1	28.00	37.00	–9.00	–24.32	55.00	–27.00	–49.09	–18.00	–32.73
Average	74	231.01	189.78	41.23	17.85	158.96	72.05	31.19	30.62	16.13

high hens, and the very lowest show an increase in the second year over the first. Out of 92 Barred Plymouth Rocks, in the first year averaging 86.14 eggs, 59 of the best were kept over into the second year. The average of the 59 in their first year was 89.50; in the second year the average was 78.61.

Of the 50 Leghorns averaging 106.88 in the first year, 28 of the best averaging 120.89 in the first year averaged in the second year 97.46.

This low second-year production of the two breeds in connection with their first-year production is additional proof that the foundation stock in these experiments was of low fecundity.

Of 561 hens with complete records for two years, there were 104 that laid more eggs the second year than the first. In the first year, these averaged 135.2 eggs, and in the second year 157.25 eggs. In the case of 35 of these hens, the records show that they started laying early and moulted in the fall and winter. This would account for a lower first-year record than the second. Of 25 others, the record shows that they started to lay late, most of them being late hatched. The fact that the 104 hens laid more in the second year than the first, therefore, may be explained in part at least by the fact that in a large number of cases environmental conditions were not favorable for high first-year production.

Limit of Production or Laying Longevity. The statement has been made by numerous authors that 600 eggs was the limit of production of a hen in a lifetime. This theory seems to have originated with a writer named Geyelin who said, "It has been ascertained that the ovarium of a fowl is composed of 600 ovula or eggs. Therefore, a hen during the whole of her lifetime cannot possibly lay more eggs than 600." This statement has been disproved by trap-nest records at this Station. Many of the station hens have laid more than 600 eggs, and a number have laid more than double 600.

Table No. LXXIV gives a list of twenty hens bred at this Station that have laid, up to the end of 1920, more than 1000 eggs. This table gives the hen number, her date hatched, and the egg record for each year. It also gives her pedigree or ancestry so far as known. It will be noted that practically all of them have high-record ancestors. It will also be noted that these hens are either direct descendants of or were closely related to 1000-egg hens. Hen C521 (Lady MacDuff) is the dam of four of these 1000-egg hens and the sire's dam of another. Lady MacDuff herself did not quite reach 1000 eggs before death, but a full sister (C547) has a record up to the end of her eighth year of 1300 eggs, which is the highest record so far secured. This hen in her ninth year is still laying well.* White Leghorn hen A27, record 1188 eggs in eight years, is the dam of two other 1000-egg hens and the sire's dam of five other 1000-egg hens. In fact, all the Leghorn 1000-egg hens are related to A27, and some of the Oregon hens of 1000-egg records carry some of her blood in the early generations.

A study of this table would indicate that the characteristic of long laying is inherited. The practical significance of the record will be apparent from the average production of the twenty hens. In the first year, the average was 235.75. There is a gradual decrease each year for five years, the average for the fifth year being 163.2. That means five

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*Since this text was written C547 died (June 11, 1921). The complete record for her entire life was 1335 eggs.

TABLE LXXIV. HENS LAYING ONE THOUSAND EGGS OR MORE

Hen No.	Breed	Date hatched	Production by years											Pedigree										
			1	2	3	4	5	6	7	8	9	10	Total	Dam	Dam's dam	Dam's dam's dam	Dam's sire's dam	Dam's sire's sire's dam	Sire's dam	Sire's dam's dam	Sire's sire's dam	Sire's sire's sire's dam	Sire's dam's sire's dam	Sire's dam's dam's dam
A27 ..	W. L.	2- 4-10	240	222	202	155	168	139	61	1+	....	....	1188	....	....	....	....	....	....	....	....	....	....	....
A60 ..	Ore.	2-19-10	177	234	226	179	142	115	62	24+	....	....	1159	....	....	....	....	....	....	....	....	....	....	....
H83N	W. L.	8-21-11	139	197	200	181	179	119	81+	....	....	....	1096	A27 *240	....	....	....	....	....	....	....	....	....	....
B14 ..	Ore.	3-19-11	215	206	208	198	189	148	81	31	2+	....	1278	250 200 202	....	....	....	....	....	....	....	....	....	....
B42 ..	Ore.	2- 5-11	228	250	184	171	135	105	119	35	54	1+	1282	Yd 8	....	....	....	....	....	....	....	....	....	....
C547 .	Ore.	4-29-12	250	225	214	192	156	108	76	79	....	....	1300	A 66 201	....	....	....	....	O 34 229	....	....	....	....	....
D328 .	Ore.	3-20-13	215	214	210	183	145	94+	....	....	....	....	1061	B 13 206 226	250 200 202	....	....	....	A 27 240	....	....	....	....	....
D351 .	Ore.	3- 7-13	247	210	192	149	141	84	....	....	....	....	1023	B8 246	250 200 202	....	....	....	A 27 240	....	....	....	....	....
E21 ..	W. L.	3-15-14	259	249	172	215	193	127+	....	....	....	....	1215	B 12 251	O 34 229	....	....	....	A 27 240	....	....	....	....	....
E37 ..	W. L.	5-18-14	217	232	134	129	200	112	....	....	....	....	1024	D399 144+ D	B9 180 203	O34 229	A27 240	O34 229	....	....	....	....	....	....
E40 ..	W. L.	5-27-14	245	218	172	191	153	61+	....	....	....	....	1040	B 12 251	O 34 229	....	....	....	A 27 240	....	....	....	....	....
E115 .	Ore.	4- 3-14	301	190	205	172	151	1+	....	....	....	....	1020	B 42 228 250	....	....	....	....	C543 291	250 200 202	A27 240	....	250 200 202	....
E215 ..	Ore.	5-11-14	283	194	191	187	172	132	....	....	....	....	1159	C521 303	A 66 201	....	O34 229	....	B 42 228 250	....	A27 240	O34 229	....	....
E218 .	Ore.	5-21-14	258	214	177	179	187+	....	....	....	....	....	1015	C521 303	A 66 201	....	O34 229	....	B 42 228 250	....	A27 240	O34 229	....	....
E260 .	W. L.	5-27-14	249	183	195	149	165	112	....	....	....	....	1053	A 27 240	....	....	....	....	O 34 229	....	....	....	....	....

E285 .	Ore.	6- 5-14	234	173	191	181	122	130	....	....	....	....	1031	C521 303	A 66 201	....	O34 229	....	B 42 228 250	.....	A27 240	O34 229	....	....
E291 .	Ore.	5-16-14	224	228	181	151	135	97	....	....	....	....	1016	C521 303	A 66 201	....	O34 229	....	B 42 228 250	.....	A27 240	O34 229	....	....
E315 .	W. L.	7-14-14	228	186	178	148	147	135	....	....	....	....	1022	C516 267	A 45 215	....	O34 229	....	A 27 240	.....	....	....	....	....
F284 .	Ore.	4- 6-15	235	210	227	192	213	.....	....	....	....	....	1077	Yd. M	.....	....	....	....	C521 303	A 66 201	B42 228 250	A27 240	O34 229	....
F621 .	W. L.	3- 2-15	271	223	203	177	171	.....	.....	....	....	....	1045	Yd. O	.....	....	....	....	D718 254	C515 241	....	....	A27 240	A27 240
Average			235.75	212.9	193.1	173.95	163.2	107	80	34	28	....												

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* In the pedigree the figures under the hen numbers represent the first-year egg production. In some cases the second year is also given.

years of profitable production. The record of the sixth year, 107 eggs, is considerably above the average production of the hens of the United States. If the flocks of the country can be bred up so that their profitable period of production will be extended from about two years to four or five years, it would mean a great saving in the cost of production. The cost of reproducing the flock, including incubation and rearing, every two years is very great. By breeding from the best layers, the poultry breeder is taking a certain method of reducing the cost of production by lengthening the profitable life of the hen.

SUMMARY

1. Individual variation in egg production is very great, ranging in our experiments from 0 to more than 300 eggs in a year.

2. This variation does not appear to be a breed characteristic.

3. The highest individual record among the Barred Plymouth Rocks was 308 and the lowest 3 eggs. The highest White Leghorn record was 302 and the lowest 1 egg. The highest among the Oregons was 309 and the lowest 14 eggs.

4. There was apparently no decrease in variation when the flock production was increased by breeding. The range between the high and the low remains about the same.

5. The highest egg record in the original or foundation stock was 218 eggs. This has been increased to 308 as the maximum in the pedigreed, high-producing stock.

6. In a supplementary experiment in a flock of the Station's strain of Oregons, kept at the Oregon State Hospital, Salem, a high record of 330 eggs was secured with a total of 17 hens laying 300 eggs or more.

7. The pullet progeny of high-record, pedigreed stock, showed a large increase in production over the unselected, low-producing foundation stock.

8. Regardless of any question of prepotency, the selection of breeding stock on the basis of high production record is a certain method of increasing production.

9. Some individuals, however, showed greater power of transmitting high fecundity than others of the same breeding.

10. Good layers were not always produced by good layers, nor were poor layers always produced by poor layers.

11. More rapid progress will be made by the breeder if he can test the breeding quality of his stock, and use for breeding those hens and males whose progeny has shown high production.

12. In a few exceptional cases, the production of the pullet progeny was higher than that of the dam and sire's dam.

13. The average production of the pullets was less than the average of the parents where the parents were selected among the highest producers, but there were individual cases where the pullet records were higher than the parents' records.

14. Breeding from the highest producers decreased the number of poor producers, but it did not decrease variability nor obviate the necessity for continuing selection of breeding stock.

15. Breeding from the highest producers showed a progressive increase in the maximum individual production, showing that the opportunity for selection was as great at the end as at the beginning of the experiment.

16. Under favorable environmental conditions, the annual record of the hen is undoubtedly the best measure of a hen's laying capacity. Where the environmental conditions are not favorable, the short-period production, monthly or bimonthly, preferably in the season of maximum

production, gives a more certain indication of inherited egg-laying capacity than the annual record.

17. There was a close relation between rate of laying, or intensity of production, and annual production. Rate of laying is within certain limits an accurate measure of egg-laying capacity.

18. Good laying capacity was indicated (1) by heavy production at the beginning of the laying year or in the fall and early winter, (2) by heavy production or high rate of laying in any one or two months of the year, (3) by heavy production at the end of the laying year. By trap-nesting for two months at the beginning of the year, or in the spring months or in the late summer and fall, the records obtained will constitute a fairly accurate basis for culling.

19. The best two-months production is a fairly accurate basis on which to select hens of best laying capacity.

20. There was a close correlation between March and April production and annual production.

21. In the Station's experimental flocks there was a greater difference in the number of eggs laid, between the best and poorest layers in March and April than in November and December, but the percentage deviation from the mean was greater in November and December than in March and April, the months of lowest and highest production.

22. Variations in vigor and environmental conditions are the disturbing factors in the study of trap-nest records.

23. With good vigor, a hen's production may extend over a longer period than may that of a hen of the same laying capacity but without the vigor.

24. Late laying in the summer and fall did not always indicate a good layer. A hen with low rate of laying and good vigor may lay late in the summer and fall.

25. Our records show on the average a higher production in the pullet year, or first laying year, than in the second or subsequent years. There was a rather consistent decrease each year. The greatest decrease was in the production of hens with highest first-year records. Where the production was very low in the first year, there was on the average an increased production in the second year.

26. The best layers in the first year, on the average, though showing the greatest decrease in the second and third years, show better records in the second and third years than poorer layers.

27. There appears to be a correlation between rate of laying and the fat content of eggs.

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Oregon Agricultural College
Experiment Station

Hood River Branch Station

Hood River Apple Orchard Management With Special Reference to Yields, Grades, and Value of Fruits

By

GORDON G. BROWN,

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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Hood River Apple Orchard Management With Special Reference to Yields, Grades, and Value of Fruit

PURPOSE

For a number of years the Hood River Branch Experiment Station has been conducting a searching investigation of the apple-orchard business in Hood River Valley. Comparatively few statistics were available which definitely indicated the economic trend towards which the fruit growers were moving. During the summer of 1915 the Office of Farm Management of the United States Department of Agriculture completed an Orchard Survey in which the cost of production was ascertained.[1] In this, a detailed study was made of the current cost factors involved in the maintenance of orchards and the handling of the crop on fifty-four farms. This survey did not, however, indicate the most profitable varieties to plant, a factor dependent largely upon yields per acre and

Fig. 1. Hood River Valley with Mt. Hood in the background. Orchards in the foreground are included in this Survey.

—*Courtesy Slocum and Donnerberg, Hood River.*

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[1] United States Department of Agriculture, Bulletin 518. Cost of Producing Apples in Hood River Valley.

price received per box. Neither was there any attempt made to segregate the orchards upon their merits as regards yields, percentage of Extra Fancy fruit produced, percentage of Four-tier sizes, and value of the product.

The present study has attempted to determine "Who's Who" in the apple business and as far as possible and practicable, the underlying causes which are associated with a high standard of success upon the one hand, and only mediocre or poor results upon the other.

Factors Under Study. The aim has been to pick out the important factors in orchard management such as pruning, thinning, propping, tillage, irrigation, and fertilizer practices and to study these with reference to differences in net results as above indicated. The differences in time spent upon these operations, and in the case of spraying for instance, the amount of material applied has been used largely as a working basis. Average costs per acre and per box in many cases have been determined. *It is desired to make plain, however, that this is not a cost-of-production study.* Costs are used very largely for relative or comparative purposes rather than for their value as cost data. The price of labor and material used in the orchard has fluctuated so much during the last few years that it seems scarcely practicable to use the figures for other purposes than as indicated.

The writer realizes the limitations surrounding a study of this kind. The data on fixed operations are made up largely from estimates which the grower was able to furnish. Statistical proof, however, is available to show that when many records are so employed, the possibility for error in final computations is reduced practically to a negligible quantity. In this survey data were secured from fifty-one orchards covering a very wide area typical of the Hood River Valley.

Data covering yields, grades, sizes, and prices per box were taken from accurate records, secured from the books of the selling agent through whose hands the fruit passed on its way to market.

PERIOD OF STUDY

The six-year period covered in this analysis is from 1913 to 1918, inclusive. This period may be said to comprise two complete epochs in the apple business in Hood River Valley. Distinct changes in orchard management took place. Tillage, cover or shade crop management, fertilizer and spraying practices were very greatly changed. This was especially true with reference to the use of fertilizer and shade crops. The use of improved spraying, high-powered machinery for application, and a more reliable spray program as compared with that of former years are factors of great importance as far as yields of high-quality fruit are concerned.

Period 1913-1915. This period may be said to comprise one epoch. Then, as was true also in former years, the apple orchard was clean cultivated. That is to say, cover or shade crops such as vetch, clover, or alfalfa, often referred to as green crops, were not, as a rule, grown between the trees for their influence in fixing nitrogen and adding humus to the soil. The result of protracted clean tillage from year to year was that the soil's humus content was gradually, and finally almost completely, "burned up."

Each year cultivation became more expensive and difficult because the soils lacking humus were more inclined to run together and cement. As a rule such soils responded less readily to irrigation because they lacked absorptive power. On hillsides they were quite subject to erosion.

Many orchards, formerly productive to a marked degree, began to fail. This was true not only of neglected orchards but also of orchards apparently receiving the very best of care as judged by the standard practices of the time. Tree growth was reduced to negative proportions; fruit-spur development was weak; and the ability of spurs to set fruit was subnormal as evidenced by small crops of fruit following very heavy blossoming.[2]

Coincident with these facts was the failure of the growers to obtain suitable control of orchard pests. Apple-scab control was not thoroughly understood by growers. During 1915, practically 25.0 percent of the fruit was lowered in grade or made unsuitable for packing from this cause alone. During 1916 considerable loss occurred from this source, but that year a much more efficient spray program was carried out by the fruit growers generally. In some orchards apple-scab infection ran as high as 63.0 percent on unsprayed trees as compared with 0.19 percent on well sprayed trees. Since 1916 very little loss has occurred from apple-scab.

Period 1916-1918. This period is indicated as the second epoch. Tillage methods were changed, and the use of shade crops, such as clover and alfalfa became very general. In some cases, the orchardist started with vetch, which was turned under after one season's growth. Clover came into general favor to be used for turning under for "green manure" after one or two season's growth. In the majority of cases alfalfa was planted directly following the use of clover or after clean tillage.

In recent years the use of nitrate of soda has also found general favor. When applied at the rate of 3 to 5 pounds to the tree under the conditions cited (i. e., lack of humus and the full establishment of a shade crop), the response was immediate, in that trees took on renewed vigor, fruit spurs functioned normally, and large quantities of higher-quality fruit were obtained.

Briefly, an improved spray program, more efficiently applied, and changed fertilizer and tillage practices are features of the second epoch.

One of the aims in this study has been to show to what extent orchards have responded to better care. This is measured in quantity of packed fruit and in grades. The object has been to show what are the possibilities in orcharding, taking trees which have arrived at full bearing age. Only trees fifteen years and older are included in the survey. Furthermore, orchards lacking in general uniformity are eliminated from the study. Many orchards could not be included in the survey because trees under full bearing age had contributed fruit of the same variety as those in full bearing, there being no segregation of records in this respect.

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[2] A report of experimental work in orchards of this character is given in the bulletin, Report of the Hood River Branch Experiment Station for 1916: Influence of Commercial Fertilizers upon the Bearing Apple Tree, by C. I. Lewis and G. G. Brown.

YIELDS

Yields for the different varieties are given in Table I in packed boxes. The figures indicate the *average annual yields* for the two three-year periods, 1913 to 1915 and 1916 to 1918; yields are also shown on an acre and tree basis on a six-year average. The percentage increase for the latter three-year period over the corresponding previous three years is indicated. Where all commercial varieties in the orchard are included in one general average it appears under the caption "Orchard". Culls and Cookers are not included in these averages.

TABLE I. AVERAGE ANNUAL YIELDS IN PACKED BOXES PER ACRE AND PER TREE FOR TWO THREE-YEAR PERIODS
(1913-1915 and 1916-1918)
(Culls and Cookers not included)

Variety	Annual average 1913-1915		Annual average 1916-1918		Percent increase†	Six-year annual acre average
	Acre	Tree	Acre	Tree		
Orchard	**215**	3.03	**314**	4.45	46.0	**264**
Gravenstein*	**829**	10.10	**836**	10.10	1.0	**832**
Winesap*	**616**	6.25	**857**	7.69	6.6	**736**
Delicious*	**656**	9.85	**767**	11.50	17.5	**710**
King	**511**	5.94	**590**	6.51	15.4	**550**
Baldwin	**484**	6.02	**524**	6.51	8.3	**504**
Red Cheek	**468**	5.73	**533**	6.92	13.8	**500**
Black Twig	**496**	5.84	**451**	5.31	.....	**473**
Ortley	**271**	4.27	**529**	7.20	95.2	**400**
Winter Banana*	**210**	3.60	**561**	6.95	167.1	**385**
Jonathan	**307**	4.29	**445**	6.39	44.9	**376**
Ben Davis	**317**	4.65	**414**	6.47	30.6	**365**
Limber Twigs*	**235**	3.25	**460**	6.39	95.7	**347**
Gano*	...	.....	...	.....	.....	**323**
Arkansas Black	**260**	3.86	**385**	5.59	47.9	**322**
Wagoner*	**239**	3.53	**296**	4.19	23.8	**267**
Spitzenburg	**200**	2.84	**312**	4.22	56.0	**256**
Newtown	**199**	2.89	**276**	3.99	38.9	**238**

*Variety averages for Winesap, Delicious, Winter Banana, Limber Twigs, Gano, and Wagoner are based upon a few records only.

†Increase percent is based upon acreage figures.

A very marked increase in yields has characterized the latter three-year period. Orchard averages increased from 215 packed boxes (1913-1915) to 314 (1916-1918) or 46.0 percent. The general six-year average is 264 boxes. These are not heavy yields, however. For trees fifteen years and older an average of 4.45 boxes a tree is not very favorable. Eighteen varieties are listed. Those giving highest averages for six years are placed ahead of those with smaller averages.

Variety Averages. Newtown, the leading commercial variety, stands last. Its average is 199 boxes (1913-1915); 276 boxes (1916-1918), with 238 for a six-year average. Spitzenburg, the other leading variety in point of acreage, stands next to last, its average being 200 boxes (1913-1915) and 312 boxes (1916-1918), with 256 as a six-year average. The fact that these main varieties do not average better is the direct cause for the low orchard averages given above. The outstanding features are the high yields for several other varieties. Annual averages for the first and second three-year periods, and for the six years respectively for the following varieties are: Delicious 656,767,710; Red Creek, 467,533,500; Black Twig, 496,451,473; Ortley 271,529,400; Jonathan, 307,445,376; Arkansas Black, 260,385.322.

TABLE II. DISTRIBUTION OF GROWERS, SHOWING AVERAGE ANNUAL YIELDS IN PACKED BOXES PER ACRE FOR THE PERIOD 1913-1918 INCLUSIVE

See Table I on average yields. Orchards are here grouped on the basis of higher or lower yields.

Group	Boxes per acre	Percentage of orchards studied								
		Orchard	King	Arkansas Black	Red Cheek	Black Twig	Ortley	Jonathan	Spitzenburg	Newtown
I	Above 500	1.80	50	18.18	60	20.0	23.00	26.30	4.29	2.22
	460-500	2.16	...	......	...	.....	7.70	10.50	2.15	2.22
	421-459	1.80	...	9.12	...	.....	7.70	......	2.15	2.22
	381-420	2.16	20	......	...	20.0	7.70	5.25	8.50	2.22
	341-380	2.16	10	......	20	20.0	15.50	......	2.15	......
	301-340	9.92	...	......	...	13.3	......	21.15	4.16	11.12
Annual Average—Boxes		**386**	**612**	**600**	**566**	**545**	**518**	**474**	**420**	**383**
Total percent		**25**	**80**	**27.30**	**80**	**73.3**	**61.60**	**63.20**	**23.40**	**20**
II	281-300	5.36	...	18.20	...	6.6	7.69	5.30	8.50	8.90
	261-280	10.72	20	18.20	...	.....	7.69	10.50	4.25	6.66
	241-260	10.72	...	9.00	...	6.6	15.42	10.50	6.40	......
	221-240	10.70	...	......	...	6.6	......	5.30	10.65	15.54
Annual Average—Boxes		**257**	**269**	**278**	...	**259**	**266**	**260**	**260**	**257**
Total percent		**37.50**	**20**	**45.40**	...	**20**	**30.80**	**31.60**	**29.80**	**31.10**
III.	181-220	25.00	...	......	20	.....	7.60	5.20	29.90	22.22
	121-180	12.50	...	......	...	6.7	......	......	16.90	20.00
	75-120	......	...	......	...	.....	......	......	......	6.68
Annual Average—Boxes		**186**	...	**146**	**212**	**177**	**193**	**195**	**186**	**169**
Total percent		**37.50**	...	**27.30**	**20**	**6.7**	**7.60**	**5.20**	**46.80**	**48.90**
Annual Grand Av.—Boxes		**264**	**550**	**332**	**500**	**473**	**400**	**376**	**256**	**238**

Orchard Groups. Table II gives yields arranged upon a different basis. The aim has been to indicate what are the possibilities for the orchard and for eight main varieties. Orchards have been placed in three groups. Those with average yields above 301 packed boxes an acre comprise Group I; those yielding from 221 to 300 boxes comprise Group II; and those below 220 comprise Group III.

A study of fifty-one orchards shows that 25.0 percent belong to Group I with a six-year average of 386 boxes; 37.5 percent belong in Group II with an average of 257 boxes; and 37.5 percent belong in Group III with an average of 186 boxes. It is apparent, therefore, that a small minority of the growers have attained a high average yield, and that more than one-third of the growers have a comparatively small average yield. It is desired that these fundamental classifications be kept in mind in order that the reader may study associated causes and facts which are discussed later.

Each of the following varieties has representatives in Group I: 27.3 percent of those growing Arkansas Black have an average yield of 600 boxes an acre; 80 percent of those growing Red Cheek average 566 boxes; 73.3 percent of those growing Black Twig average 545 boxes; 61.6 percent of those growing Ortley average 518 boxes; and 63.3 percent of those growing Jonathan average 474 boxes. Upon this basis both Spitzenburg and Newtown show to a disadvantage, only 23.4 percent of Spitzenburg growers having an average of 420 boxes and 20 percent of the Newtown growers averaging 383 boxes.

Culls and Cookers. In addition to the number of packed boxes of Standard Grades recorded, the orchard must be credited also with tonnage of fruit of lower grades. These are commercially known as Culls or Cookers. The former, composed of windfalls and other low-grade fruit, are used principally for cider and vinegar manufacturing. Cookers are sold either for canning or for the fresh-fruit trade. In the latter case they are packed "face and fill" style. The average tonnage for culls and cookers is 1524 pounds an acre, the equivalent of approximately 32 packed boxes. This, together with 314 packed boxes (1916-1918 Table I) gives a total of 346 boxes an acre.

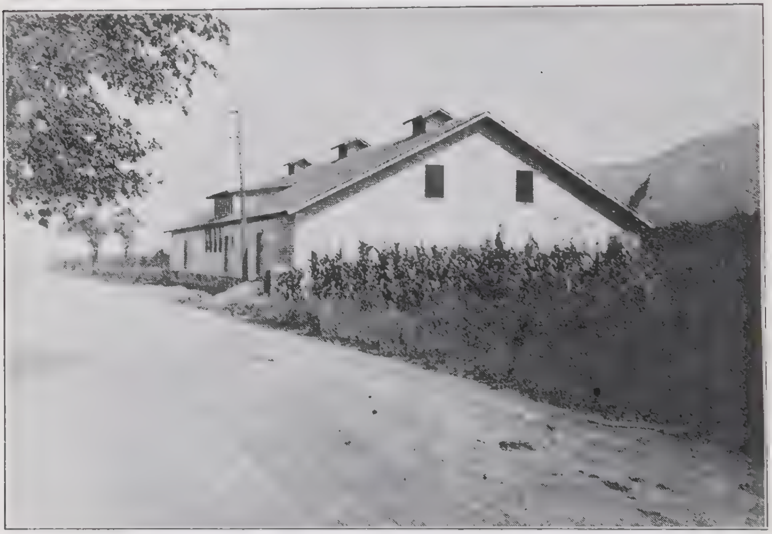

Fig. 2. A typical packing house in Hood River Valley. The building is equipped with "Cutler" fruit grader. It also includes "common storage" facilities.

GRADES

Packing and Grading Rules. The following statement comprises the chief requirements of the packing and grading rules of the Apple Growers Association of Hood River.

Extra Fancy. This grade is defined as smooth, mature, clean, hand-picked, well-formed apples only, free from all insect pests, diseases, blemishes, bruises or other physical injuries, scald, fungus, scale, dry or bitter rot, worms, worm stings, worm holes, spray burn, limb rub, visible water core, skin puncture, or skin broken at the stem.

Fancy. This grade is defined as apples complying with the standard of first-grade apples, except that slight leaf rubs, scratches, or russeting shall be permitted up to a total of one inch in diameter in counts running 125 or less to the box, or three-fourths of one inch in diameter in counts running 138 to 163 to the box, and one-half inch in diameter in counts running 175 or more to the box in all cases where the color requirements are equal to the color rules provided for this grade. Limb rubs are permitted showing an aggregate area in the various counts of one-half the diameter of that allowed by leaf rubs.

"C" Grade. This grade is to consist of mature, hand-picked apples free from all insect pests, worms, worm holes, infectious diseases, skin punctures, bruises, or broken skin; but slightly misshapen apples or those having slight sun scald and not to exceed two healed-over stings and blemishes allowed for Fancy grade may be permitted. All apples of striped or red varieties must have a tinge of color.

Grades and Sizes by Percentages. Table III summarizes data covering percentages of Extra Fancy, Fancy, and Choice, also Four, Four-and-one-half, and Five-tier sizes for the years 1913-1918 inclusive. These figures were furnished by the Apple Growers Association which handles approximately seventy percent of the apple tonnage of Hood River Valley. It should be stated that these figures cover general Valley conditions, fruit coming from both young and old orchards. The tendency would naturally be to secure larger fruit from the younger trees and smaller fruit from the older trees. These data should not be confused with the data in tables IV and V, which summarize grades for the orchards covered in this survey.

It will be noticed that the percentage of Extra Fancy dropped from 37 percent in 1914 to 30 percent in 1915; while "C" Grade, from which little returns are derived, increased from 20 to 33 percent. A very encouraging increase in Extra Fancy fruit is noted for 1917 and 1918, averages being 52 and 51 percent respectively as compared with 38 percent, the best previous record. The grand average for Extra Fancy for the period 1913-1915 is 34.6 percent as compared with 47.0 percent for 1916-1918. Owing to the fact that best returns are derived only from Extra Fancy and Fancy fruit, these two grades are totaled in Table III.

TABLE III. PERCENTAGES ACCORDING TO GRADES AND SIZES FOR THE YEARS 1913-1918 INCLUSIVE

These figures apply to approximately seventy percent of the apple tonnage for the Hood River Valley.

Year	1913	1914	1915	Average	1916	1917	1918	Average	Grand average
Grades									
Extra Fancy (percent)	37	37	30	**34.6**	38	52	51	**47.0**	**40.8**
Fancy (percent)	43	43	37	**41.0**	37	32	32	**33.6**	**37.3**
Total (percent)	80	80	67	**75.6**	75	84	83	**80.6**	**78.1**
"C" Grade (percent)	20	20	33	**24.3**	25	16	17	**19.3**	**21.8**
Tier Sizes									
Four tier (125 and larger) (percent)	58	57	64	**59.6**	42	40	61	**47.6**	**53.6**
Four and one-half tier (138-163) (percent)	28	31	23	**27.4**	37	36	27	**33.4**	**30.3**
Total (percent)	86	88	87	**87.0**	79	76	88	**81.0**	**83.9**
Five tier (175-225) (percent)	11	12	13	**13.0**	21	24	12	**19.0**	**16.0**

Data furnished by Apple Growers Association.

Grades and Sizes for Orchards Surveyed. Table IV summarizes the average yearly percentage of Extra Fancy fruit and sizes four-tier and larger for the two three-year periods (1913-1915 and 1916-1918). This summary includes orchard averages and also variety averages for Newtown, Arkansas Black, Ortley, Jonathan, Spitzenburg, and Red Cheek. All varieties show a substantial increase in percentage of Extra Fancy fruit. On the other hand a decrease in percentage of Four-tier and larger has also been a feature, the average decrease ranging from a minimum of 3.2 percent (Ortley) to a maximum of 19.4 percent (Jonathan). These figures, as is also true in Table V, refer specifically to orchards covered in this survey, and should not be confused with those given in Table III, which refer to general orchard averages for the entire Valley. The decrease in sizes would naturally be associated with older trees such as those covered in the survey. The Arkansas Black is the only variety of the six listed which shows a favorable increase in size of fruit, the percentage being 5.8.

TABLE IV. AVERAGE YEARLY PERCENTAGE OF EXTRA FANCY FRUIT AND SIZES FOUR-TIER AND LARGER FOR THE TWO THREE-YEAR PERIODS 1913-1915, AND 1916-1918 INCLUSIVE

(See also Table V on grades.)

Variety	Percentage extra fancy						
	Orchard	Newtown	Arkansas Black	Ortley	Jonathan	Spitzenburg	Red Cheek
1913-1915	39.6	41.0	40.5	33.5	42.4	32.8	....
1916-1918	**49.8**	**55.0**	**51.1**	**55.5**	**45.2**	**52.6**	....
Increase	10.2	14.0	9.6	22.0	2.8	19.8	....
Average	**44.7**	**48**	**45.8**	**44.5**	**43.8**	**42.7**	**31**

Variety	Percentage four-tier and larger						
	Orchard	Ortley	Arkansas Black	Red Cheek	Spitzenburg	Newtown	Jonathan
1913-1915	56.6	73.7	65.9	69.4	60.4	52.3	41.6
1916-1918	**44.2**	**70.5**	**71.7**	**60.2**	**44.5**	**39.3**	**22.2**
Decrease	12.4	3.2	....	9.2	15.9	13.0	19.4
Average	**50.4**	**72.1**	**68.8**	**64.8**	**52.4**	**45.8**	**31.9**

Orchard Groups, Extra Fancy. Table V arranges the growers into groups according to the percentage of Extra Fancy fruit produced upon a six-year average. This is another fundamental classification against which related factors are checked in later tables. Those averaging above 51 percent Extra Fancy are placed in Group I; those with 41 to 50 percent in Group II; those below 40 percent in Group III. Taking orchard averages, 23.1 percent of the growers average 55 percent Extra Fancy; 50 percent of growers average 44.9 percent; and 26.9 percent average 35.3 percent. The figures also point out strongly that it is apparently easier to produce a higher percentage of Extra Fancy Newtowns than any of the other varieties listed. For example 42.5 percent of the Newtown growers produce 54.9 percent Extra Fancy as contrasted with 23.4 percent Spitzenburg growers with an average of 55.2 percent. On the other hand only 14.9 percent of the Newtown growers average as low as 34.9 percent Extra Fancy as compared with less than 33.6 percent Extra Fancy from 42.6 percent of the growers of Spitzenburg, 36.4 percent Arkansas Black, 31.2 percent Ortley, and 28.6 percent Jonathan.

TABLE V. DISTRIBUTION OF GROWERS SHOWING RANGE IN PERCENTAGE OF EXTRA FANCY FRUIT AND FOUR-TIER SIZES FOR THE PERIOD 1913-1918 INCLUSIVE.

(See Table IV for further data on grades and sizes.)

	Percent extra fancy	Percentage distribution of growers with extra fancy						
		Orchard	Newtown	Spitzenburg	Arkansas Black	Ortley	Jonathan	Red Cheek
Group I.	61- 70	2.0	2.10	4.20	18.1	8.33	.....	....
	51- 60	21.1	40.40	29.20	9.1	4.17	23.83	....
Total percent of growers		23.1	42.50	23.40	27.2	12.50	23.83	....
Average percent extra fancy		**55.0**	**54.90**	**55.20**	**62.0**	**61.30**	**54.00**	....
Group II.	41-50	50.0	42.60	34.00	36.4	56.30	47.60	16.6
Average percent extra fancy		**44.9**	**46.10**	**46.10**	**46.5**	**44.80**	**45.10**	**48.0**
	31-40	23.1	12.80	31.90	27.3	15.60	23.80	50.0
Group III.	21-30	3.8	2.10	10.70	9.1	15.60	.....	....
	10-20	....	.....	.....	....	.....	4.77	33.4
Total percent of growers		26.9	14.90	42.60	36.4	31.20	28.57	83.4
Average percent extra fancy		**35.3**	**34.10**	**33.60**	**33.0**	**31.20**	**33.10**	**25.8**

	Percent four-tier	Percentage distribution of growers with four-tier sizes						
		Orchard	Newtown	Spitzenburg	Ortley	Arkansas Black	Jonathan	Red Cheek
	91-100	....	.....	.....	6.6	.....	.....	....
Group I.	81- 90	....	.....	.....	33.3	.....	.....	....
	71- 80	4.0	2.15	4.44	26.7	50.00	.....	50.0
	61- 70	13.8	4.30	15.50	....	20.00	.....	16.7
Total percent of growers		17.8	6.45	19.94	66.6	70.00	.....	66.7
Average percent four-tier		**65.0**	**67.00**	**68.00**	**81.8**	**75.00**	.....	**72.9**
Group II.	51- 60	35.3	27.60	42.20	26.9	30.00	5.30	....
	41- 50	27.6	38.30	22.20	....	.....	15.80	33.3
Total percent of growers		62.9	65.90	64.40	26.9	30.00	21.10	33.3
Average percent four-tier		**51.5**	**48.90**	**52.70**	**53.7**	**58.00**	**47.50**	**49.0**
	31- 40	15.7	19.10	8.88	6.5	.....	42.10	....
Group III.	21- 30	3.6	8.55	4.44	....	.....	10.50	....
	0- 20	....	.....	2.34	....	.....	26.30	....
Total percent of growers		19.3	27.65	15.66	6.5	.....	78.90	....
Average percent four-tier		**33.0**	**32.90**	**31.40**	**36.6**	.....	**27.70**	....

Orchard Groups, Four-tier Sizes. The orchards have also been grouped according to their record in producing Four-tier sized fruit (125 to box and larger). This is an important consideration, the larger fruit, as shown in Table VI giving much higher net returns. Those growers producing above 61 percent Four-tier fruit are placed in Group I; those ranging from 41-60 percent constitute Group II; and those below 40 percent, Group III. The average distribution in this respect shows up better for Spitzenburg than for Newtown, there being 19.9 percent of the former growers in Group I as compared with 6.45 percent for the latter. This fact causes a very high percentage of Newtown growers to fall in Group III, 27.6 percent as compared with 15.6 for Spitzenburgs.

PRICES RECEIVED FOR FRUIT

Table VI indicates the average net price received by the fruit grower from his selling agent. The figures represent a six-year average for each of twenty varieties grown in the Valley. Notice is directed to the fact that price is indicated both upon the basis of Extra Fancy, Fancy, and Choice Grades and also for Four, Four-and-one-half, and Five-tier sizes.

The varieties are arranged upon the basis of higher to lower prices a box received by the grower. It is noteworthy that the two varieties grown at Hood River in greatest quantity; namely, Newtown and Spitzenburg, do not command the highest average price. This is true, not only upon a six-year-average basis, but also upon a yearly basis. Records show that the general rating given the different varieties upon a six-year basis quite closely indicates also their relative popularity from year to year. Delicious and Winter Banana have consistently "topped the market" for six years. The former is grown only in limited quantity at Hood River, and Winter Banana does not comprise a large acreage especially in the orchards studied.

TABLE VI. AVERAGE NET PRICE PER BOX RECEIVED BY GROWERS FOR APPLES DURING THE YEARS 1913-1918, INCLUSIVE

These prices are used as a working basis for determining value of fruit per acre and net profits as shown in later tables.

Grade	Extra fancy			Fancy			Choice		
Tier	4	4½	5	4	4½	5	4	4½	5
Delicious	1.808	1.528	1.300	1.377	1.282	1.050	1.100	.985	.772
Winter Banana	1.756	1.544	1.238	1.381	1.254	1.008	1.024	.924	.708
Arkansas Black	1.577	1.363	1.058	1.400	1.240	1.000	1.068	.910	.800
Winesap	1.477	1.302	1.175	1.248	1.147	1.035	.960	.862	.692
Spitzenburg	1.491	1.324	1.136	1.259	1.113	.946	.991	.863	.721
Newtown	1.363	1.253	1.099	1.191	1.098	.924	.976	.901	.839
Oregon Red*	1.199	1.094	.812	.....	.....	.....	.....	.....	.....
Ortley	1.383	1.217	1.013	1.208	1.050	.883	.982	.685	.625
Gravenstein	1.126	1.009	.831	1.319	1.205	.933	1.042	.904	.650
King	1.073	1.058	1.021	1.132	1.061	.954	.972	.875	.891
Jonathan	1.206	1.120	.991	1.048	.975	.850	.903	.797	.685
Red Cheek	1.409	1.227	.877	1.212	1.014	.591	.899	.761	.569
Northern Spy	.....	.....	.....	1.138	1.146	.840	.938	.853	.678
Gano	.....	.....	.....	1.072	.935	.758	.848	.758	.568
Black Twig	.995	.755	.690	1.016	.895	.763	.825	.676	.623
Wagener	.....	.....	.....	1.008	.807	.715	.837	.700	.570
Baldwin	.....	.....	.....	1.001	.839	.699	.788	.636	.611
Stark	.....	.....	.....	1.015	.877	.704	.800	.630	.539
Delaware Red	.....	.....	.....	.991	.794	.682	.780	.691	.612
Ben Davis	.....	.....	.....	.858	.816	.683	.696	.611	.528
Average	**1.374**	**1.215**	**1.019**	**1.151**	**1.028**	**.843**	**.917**	**.790**	**.669**

* Oregon Red is the trade name for Extra Fancy Baldwin.

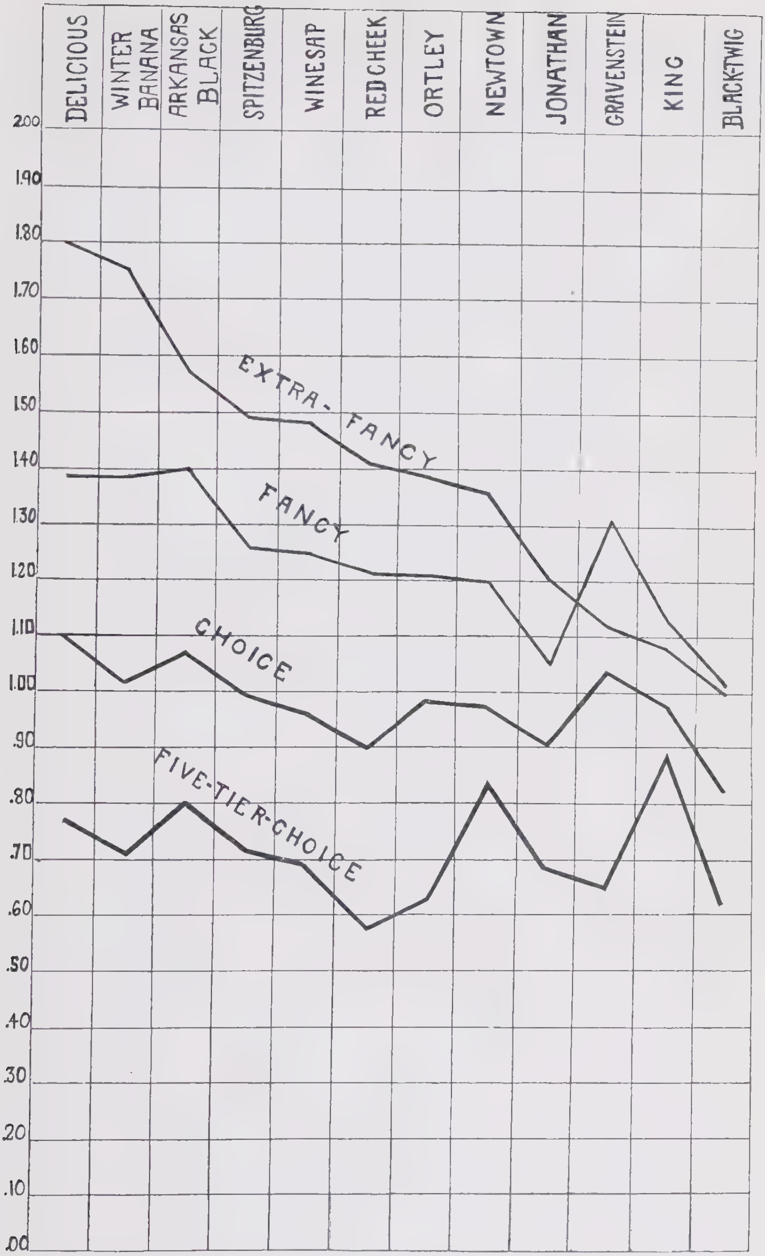

Fig. 3. (Supplements Table VI.) Six-year average prices paid for Four-tier Extra Fancy, Fancy and Choice; also for Five-tier Choice.

That the large-sized fruit has commanded a premium is quite clearly shown. For instance, Four-tier Extra Fancy Spitzenburgs averaged $1.49 a box; Four-and-one-half-tier, $1.324; Five-tier, $1.136. The same is also true of other grades. It is also notable that larger fruit in a lower grade commanded a higher price than a smaller apple in a higher grade. For instance Four-tier, Fancy Spitzenburg averaged $1.259 as against $1.136 for Five-tier Extra Fancy. Attention is called to the price paid for the following varieties inasmuch as they constitute the largest acreage. The price given is for Four-tier for each of the following grades: Extra Fancy, Fancy, and Choice: Newtown, $1.36, $1.19, $0.97; Spitzenburg $1.49, $1.259, $0.99; Ortley, $1.38, $1.208, $0.98; Jonathan $1.206, $1.048, $0.903; Red Cheek, $1.409, $1.21, $0.899; Arkansas Black, $1.57, $1.40, $1.068. Ben Davis stands last with prices ranging from $0.858 for Fancy to $0.696 for Choice.

Figure 3 represents in a graphic way prices received during the period 1913-1918 for fruit Four-tier Extra Fancy, Fancy, and Choice; and Five-tier, Choice.

GROSS VALUE OF FRUIT PER ACRE AND BOX

Orchard Groups. Table VII points out the gross annual value of fruit per acre and per box for the period 1913-1918 inclusive. This is another fundamental classification, in that orchards are grouped upon the basis of high or low money returns. Group I is composed of growers whose returns range from $351.00 an acre to above $600.00; 24.4 percent of the growers fall within this group with an average of $461.00 an acre or $1.29 a box. Group II represents values ranging from $251.00 to $350.00 per acre with an average of $290.00; 40.9 percent of the growers fall within this group with a box value of $1.15. Group III comprises 34.7 percent of the growers whose gross fruit value ranges from $100.00 to $250.00 per acre with an average of $204.00; the average value per box is $1.14.

Table VII further reviews, upon a similar group basis, acre and box fruit values. Red Cheek stands first with a grand acre value of $588.00. Next in order is the Ortley with $449.00; Arkansas Black, $442.00; Jonathan, $373.00; Spitzenburg, $326.00; Newtown, $289.00. Owing to the fact that the foregoing are standard varieties they have been thus grouped. King, Baldwin, Ben Davis, and Black Twig are not considered as such at Hood River because of their limited acreage. Consequently they have been grouped together in the table. Kings lead with an average of $632.00, followed by Baldwin with $473.00; Ben Davis, $351.00; and Black Twig, $335.00.

RELATION OF GROSS VALUE TO GRADES AND YIELDS

Table VIII indicates the interrelations existing between gross annual value of fruit per acre *(see classification Table VII)* and average yields as expressed in packed boxes per acre; also percentages of Extra Fancy fruit and Four-tier sizes. Figures relate to general orchard averages, also to Newtowns and Spitzenburgs.

Orchards in Group I with an average value of $461.00 an acre do not show marked differences in percentages of Extra Fancy or Four-tier sizes as compared with orchards in Groups II and III, which show

TABLE VII. GROSS ANNUAL VALUE OF FRUIT PER ACRE AND PER BOX FOR THE PERIOD 1913-1918 INCLUSIVE. The value of fruit is figured on the basis of the average net price to the grower from his sales agent. *See* Table VI.

Group	Acre value of fruit in dollars	Percentage of growers										
		Orchard	Red Cheek	Ortley	Arkansas Black	Jonathan	Spitzenburg	Newtown	King	Baldwin	Ben Davis	Black Twig
I.	Above $600.00	2.04	50.00	20.00	18.20	11.80	4.60	6.80	50.00	30.00	......	7.70
	$551.00 to $600.00	6.12	......	6.60	9.10	5.90	4.60	3.25	12.50	......	......	......
	$501.00 to $550.00	......	......	......	......	5.90	4.60	......	12.50	10.00	16.60	......
	$451.00 to $500.00	2.04	16.60	......	......	5.90	4.60	3.25	......	20.00	......	......
	$401.00 to $450.00	6.04	16.70	33.30	9.10	......	4.60	......	......	10.00	16.60	7.70
	$351.00 to $400.00	8.16	......	6.70	18.10	11.70	10.60	14.00	......	......	33.40	15.30
Total percent of growers		**24.40**	**83.30**	**66.60**	**54.50**	**41.20**	**33.60**	**27.30**	**75.00**	**70.00**	**66.60**	**30.70**
Average value per acre		**461**	**660**	**543**	**592**	**522**	**481**	**469**	**745**	**572**	**414**	**452**
Average value per box		**1.29**	**1.45**	**1.24**	**1.34**	**1.14**	**1.29**	**1.33**	**1.12**	**.96**	**.99**	**.96**
II.	$301.00 to 350.00	12.30	......	6.80	18.20	17.60	30.20	9.10	......	......	......	......
	$251.00 to $300.00	28.60	......	20.00	9.10	17.60	9.30	13.60	......	......	......	......
Total percent of growers		**40.90**	......	**26.80**	**27.30**	**35.30**	**39.50**	**22.70**	**25.00**	**20.00**	......	**46.20**
Average value per acre		**290**	......	**290**	**298**	**303**	**289**	**297**	**293**	**308**	......	**318**
Average value per box		**1.15**	......	**1.19**	**1.43**	**.92**	**1.23**	**1.14**	**1.01**	**.94**	......	**.85**
III.	$201.00 to $250.00	22.50	16.70	......	9.10	17.60	13.90	22.70	......	......	......	......
	$151.00 to $200.00	10.20	......	......	9.10	5.90	13.90	15.90	......	......	......	......
	$100.00 to $150.00	2.00	......	6.60	......	......	......	11.40	......	......	......	......
Total percent of growers		**34.70**	**16.70**	**6.60**	**18.20**	**23.50**	**27.90**	**50.00**	......	**10.00**	**33.40**	**23.10**
Average value per acre		**204**	**225**	**143**	**208**	**222**	**199**	**188**	......	**110**	**225**	**214**
Average value per box		**1.14**	**1.06**	**1.25**	**1.39**	**.94**	**1.21**	**1.09**	......	**.76**	**.74**	**.91**
Grand acre value		304	588	449	442	373	326	289	632	473	351	335
Grand box value		1.18	1.39	1.22	1.37	1.02	1.24	1.17	1.09	.94	.91	.89

Note—King, Baldwin, Ben Davis, and Black Twig data are based upon fewer records than the other standard varieties in Table VIII.

values of $290.00 and $204.00 an acre respectively. Group I (orchard average) shows 46.0 percent Extra Fancy; Group II, 47.0 percent; and Group III, 44.0 percent. Only slight differences in percentages obtain between each group for both Newtowns and Spitzenburgs. Group I (orchard average) shows 49.0 percent Four-tier; Group II, 51.0 percent; and Group III, 47.0 percent. Similarly, only slight differences are recorded in this respect between Newtown and Spitzenburg.

Table VIII points out strikingly the big factor as related to higher or lower values of fruit to the acre, that of relative yields. Group I shows an orchard average of 365 packed boxes; Group II, 251 boxes; and Group III, 182 boxes or only approximately 50 percent that of Group I. A similar striking relation is indicated for Newtowns and Spitzenburgs, Group I showing 368 boxes and 370 boxes respectively; Group II, 230 and 263 boxes; and Group III, 165 boxes and 186 boxes.

TABLE VIII. RELATION OF GROSS ANNUAL VALUE OF FRUIT PER ACRE FOR THE PERIOD 1913-1918, INCLUSIVE, TO AVERAGE ANNUAL YIELDS PER ACRE AND PERCENTAGES OF EXTRA FANCY FRUIT AND FOUR-TIER SIZES.

(See also Table VII. on value of fruit per acre.)

Group	Orchard average				Newtown			Spitzenburg		
	Gross value of fruit per acre dollars	Boxes per acre	Percent		Boxes per acre	Percent		Boxes per acre	Percent	
			Extra fancy	Four tier		Extra fancy	Four tier		Extra fancy	Four tier
I	461	**365**	46	49	**368**	49	45	**370**	42	47
II	290	**251**	47	51	**230**	50	46	**263**	45	55
III	204	**182**	44	47	**165**	45	43	**186**	41	48

Note—Group I. represents 24.4 percent of the orchards studied; Group II., 40.9 percent; Group III., 34.7 percent.

RELATIVE ORCHARD ACREAGES, AGE, AND NUMBER OF TREES PER ACRE, PLANTING PLAN, AND VARIETIES

In Table IX, the relation between yields of Extra Fancy, Four-tier (groups I, II, and III) and the size of bearing orchard is studied. The table points out unmistakably the fact that large yields and small acreages appear to be most compatible; while vice versa, small yields and large acreages go hand in hand. This might not be an invariable result and probably does not obtain in all instances, but on an average the foregoing facts are very evident. The greatest factor is undoubtedly the fact that on small acreages closer supervision to details is given by the grower, who is usually the owner. Spraying is more timely, irrigation is more thorough, etc. On the larger ranches much labor is hired, and often inefficiency creeps in. Yet the small grower does not necessarily possess the most economical unit. That is a matter largely dependent upon labor distribution and especially volume of business. It will be readily understood that where the margin of profit per box is small the small grower is at a disadvantage.

TABLE IX. RELATION OF YIELDS OF EXTRA FANCY AND GROSS VALUE OF FRUIT PER ACRE TO SIZE OF ORCHARD AND FARM, AGE AND NUMBER OF TREES PER ACRE; PLANTING PLAN AND NUMBER OF VARIETIES (1913-1918).

Group No.	Boxes per acre	Size of orchard					Non-bearing	Total orchard	Other land	Total Size of farm	Age of trees	Trees per acre	No. of standard varieties	Percentage of growers with planting plan		
		Percent of growers														
		10+ A.	11-20 A.	21-30 A.	30+ A.	Average								Hexagonal	Square	Both systems
		%	%	%	%	acres				acres	years			%	%	%
I.	**386**	19.80	5.80	1.85	.00	**10.01**	7.13	17.14	11.56	**28.70**	16.90	**76**	4	3.80	15.80	7.70
II.	**257**	9.80	21.50	.00	2.03	**14.46**	4.90	19.36	10.22	**29.58**	15.40	**69**	4	17.40	13.47	3.90
III.	**186**	7.84	17.60	3.92	9.86	**25.73**	2.17	27.90	6.95	**34.85**	14.60	**70**	4	23.00	9.20	5.80
Total and average		37.44	44.90	5.77	11.89	**17.94**	4.05	21.99	10.06	**32.05**	15.60	**71**	4	44.20	38.40	17.40
	Percent	*Relation to percentage extra fancy fruit*														
I.	**55.0**	8.70	13.00	2.19	2.19	**16.50**	....	....	....	....	....	....	....	....	....	....
II.	**44.9**	23.90	21.70	.00	4.40	**17.00**	....	....	....	....	....	....	....	....	....	....
III.	**35.3**	4.35	10.90	2.17	6.50	**23.69**	....	....	....	....	....	....	....	....	....	....
Total and average		13.09	36.95	45.60	4.36	**17.94**	....	....	....	....	....	....	....	....	....	....
	Value	*Relation to gross value fruit per acre*														
I.	**461**	20.00	6.66	.00	.00	**9.55**	....	....	....	....	16.20	....	....	....	....	....
II.	**290**	11.11	26.66	.00	4.45	**16.35**	....	....	....	....	15.60	....	....	....	....	....
III.	**204**	4.44	13.32	4.44	8.92	**30.49**	....	....	....	....	14.43	....	....	....	....	....
Total and average		35.55	46.64	4.44	13.37	**17.94**	....	....	....	....	15.60	....	....	....	....	....

Table IX indicates that growers in Group I (386 boxes) manage only 10.01 acres of bearing orchard; those in Group II (257 boxes) average 14.46 acres, and those in Group III, 25.73 acres. The same relations exist with reference to percentages of Extra Fancy. Growers in Group I (55 percent) manage 16.50 acres; in Group II (44.9 percent), 17 acres; in Group III (35.3 percent), 23.69 acres. The relation between gross value of fruit to the acre and acreage closely resembles the relation already discussed between yields and acreage. This is what might be expected, inasmuch as high yields and high gross values go hand in hand.

Orchardists with high average yields apparently possess a slight advantage in that they have 76 trees an acre, as compared with 69 and 70 trees for Group II and Group III. This fact may be considered an advantage while trees are comparatively young, since the ground is not fully occupied by the root system of trees. As trees reach full maturity, however, there is a possibility that trees set at a greater distance may prove equally if not more productive.

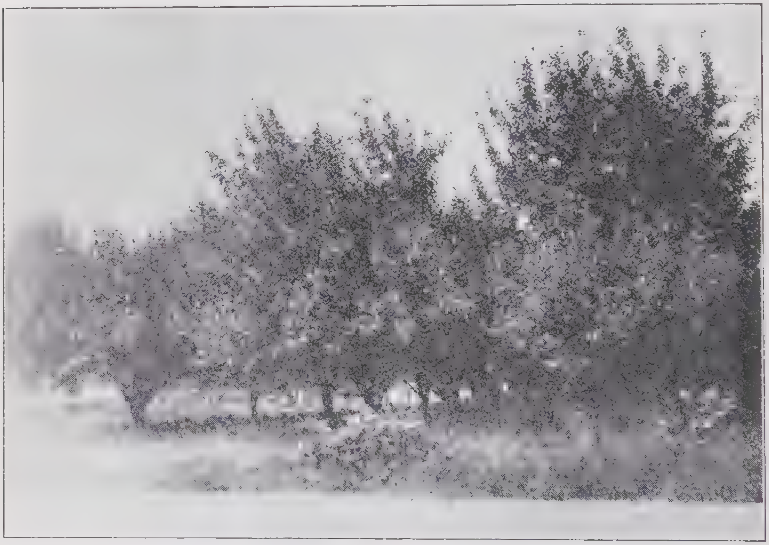

Fig. 4. Trees set 24 feet apart on the "square" system. They are already crowding. Close planting pays while trees are young but will probably react unfavorably as trees become older.

SHADE CROP MANAGEMENT

Table X shows the relation of yields, percentages of Extra Fancy and Four-tier, and gross value of fruit, to shade crop management. By "shade crops" are meant those leguminous crops which usually occupy the ground between the trees for one year or more. Clover is usually allowed to grow two years from the time of seeding, whereas alfalfa may be left for a number of years. The former crop is usually seeded with the idea of securing a quick stand to be plowed under as a "green manure" crop for the purpose of providing humus for the soil. On the other hand it is the common conception that alfalfa gives greatest benefits after it has become fully established with a deep rooting system. Both crops are highly valued because of their ability to fix nitrogen in the soil through the agency of their "nitrifying bacteria" working through the nodules on the roots. In many cases the grower inoculates his seed with bacteria obtained from pure culture.

TABLE X. RELATION OF YIELDS, GRADES, SIZES, AND GROSS VALUE OF FRUIT PER ACRE (1913-1918) TO SHADE-CROP MANAGEMENT.

Group	Boxes per acre	Percent of orchard in shade crop												Percent plowed under
		Alfalfa			Clover			Other			Total			
		1913-1915	1916-1918	Average	1913-1915	1916-1918	Average	1913-1915	1916-1918	Average	1913-1915	1916-1918	Average	
Relation to Yields														
I	386.0	18.6	48.3	33.40	28.3	31.5	34.90	3.05	.00	1.52	59.90	79.80	69.87	14.50
II .. .	257.0	19.0	62.9	40.90	31.6	22.3	26.90	3.50	1.30	2.40	51.10	86.50	70.30	9.9
III	186.0	17.9	40.7	29.30	16.2	23.4	19.80	2.26	4.04	3.15	36.36	68.14	52.25	4.30
Relation to Percent Extra Fancy														
I	55.0	27.8	63.0	45.40	19.5	16.4	17.90	2.30	.43	1.36	49.60	79.80	64.71	6.10
II	44.9	11.4	44.5	27.95	20.6	27.0	23.80	2.80	.20	1.50	31.80	71.70	53.25	12.80
III	35.3	16.2	52.4	34.30	13.0	25.0	19.02	5.49	8.90	7.19	34.69	86.35	60.51	6.40
Relation to Four-tier and Larger														
I	65.0	9.4	59.8	34.60	29.5	15.0	22.25	3.70	.00	1.85	42.60	74.80	58.70	9.37
II	51.5	20.7	57.6	39.15	25.8	20.0	22.90	3.10	.17	1.63	49.60	77.80	63.68	9.20
III	33.0	3.4	21.1	12.25	19.0	44.8	31.90	1.50	1.50	1.50	23.90	67.30	45.65	4.80
Relation to Gross Value of Fruit per Acre														
I	461.0	11.4	69.6	40.50	31.9	17.2	24.50	3.40	.00	1.70	46.70	86.80	66.70	12.40
II	290.0	17.4	36.0	26.70	23.4	25.4	24.40	3.50	1.40	2.45	44.30	62.80	53.50	7.90
III	204.0	22.2	43.5	32.85	21.5	27.5	24.50	.60	.60	.60	44.30	71.60	57.95	5.90

The data show clearly that the grower fully appreciates the value of such shade or green crops. The percentage of the orchard in shade crops on a six-year average has been obtained as follows: Since the total possibility for 100-percent use of shade crops during this period is six times the total orchard acreage, dividing the total annual acreage actually so employed by the product consequently gives the percentage. Group I (386 boxes an acre) has made approximately equal use of both alfalfa and clover. In the former case the percentage is 33.4 and in the latter 34.9, with a total six-year average of 69.8 percent. Groups II and III (257 and 186 boxes) have used alfalfa more than clover. Their total percentages are 70.3 and 52.25 respectively.

On an average the grower's percentage of acres in shade crops plowed under is small. The orchards with the poorest average yields (Group III) show only 4.3 percent, whereas Group I shows 14.5 percent.

WAGES AND LABOR CHARGES

Table XI indicates the basis upon which orchard costs are determined. Wages are classified under three general heads; labor, which indicates the price paid the ordinary "hired man"; spraying, which covers the prevailing wages for sprayer with two men and team; and team work used in cultivation, cartage, etc. Labor costs have advanced considerably since 1916. The yearly average for labor is placed at $2.33 a day; spraying, $11.33; and team work, $5.66.

TABLE XI. WAGES PER DAY BASIS OF LABOR CHARGES IN DETERMINING COSTS OF ORCHARD OPERATION

Kind of labor	Average ruling wage per year						Yearly average
	1913	1914	1915	1916	1917	1918	
Labor	$ 2.00	$ 2.00	$ 2.00	$ 2.50	$ 2.50	$ 3.00	$ 2.33
Spraying (3-man outfit)	10.00	10.00	10.00	10.00	13.00	15.00	11.33
Team-work	5.00	5.00	5.00	6.00	6.00	7.00	5.66

COST OF MATERIALS USED

Table XII shows the basis upon which the cost of materials used in apple production has been computed. The figures given represent an average for the five years (1914-1918). All materials have shown a substantial increase in price varying approximately from 10 to 30 percent. Miscible oil and lime-sulfur are figured on a uniform basis of 100 gallons. The former cost $34.80 and the latter $14.16. The cost of lead arsenate paste has been $8.06 for 100 pounds; powder, $19.87; whale-oil soap $9.17; copper sulfate, $12.25; quicklime, $0.96. Nitrate of soda has been used to a considerable extent in the Valley since 1915 and 1916. During those years the price was $60.00 a ton. Its average is $92.00. The "Beaver Brand Mixed Fertilizer", sold in considerable quantities during the first two years covered by the survey, averaged $55.00 a ton.

TABLE XII. AVERAGE COST OF MATERIALS USED IN ORCHARD OPERATIONS, AVERAGE FOR FIVE YEARS. USED AS BASIS OF PRODUCTION COSTS.

Material	Miscible oil	Lime-sulfur	Black-Leaf 40	Lead arsenate paste	Lead arsenate powder	Whale-oil soap	Copper sulfate	Lime	Nitrate of soda	"Beaver brand fertilizer"
100 gallons	$34.80	$14.16	......	......	......	......	......	......	......	......
100 pounds	......	......	......	$ 8.06	$19.87	$ 9.17	$12.25	$ 0.96	......	......
10 pounds	......	......	$10.75	......	......	......	......	......	......	......
1 ton	......	......	......	......	......	......	......	......	$92.00	$55.00

NITRATE OF SODA AND MANURE APPLIED, LIVESTOCK—COSTS

Table XIII shows the status of fertilizer practices in Hood River Valley. Nitrate of soda has been used by practically all growers in amounts varying from 2 to 6 pounds a tree. In some cases individual growers have used 8 pounds in a single application. As a rule the grower applies 3 pounds in early March to a full-grown, bearing apple tree. In some cases annual applications are made. In other cases such fertilizer is applied during the year when a heavy crop of apples is expected. The Hood River Experiment Station has been testing nitrate of soda and other fertilizers for a number of years under typical conditions.[3]

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[3] Results of these tests are summarized in Oreg. Agric. Col. Exp. Sta. Bul. 166, Fertilizers for Oregon Orchards; in the 1914-1915 Report of the Hood River Branch Experiment Station; and in Oreg. Agric. Col. Exp. Sta. Bul. 141, Report of the Hood River Branch Experiment Station for 1916.

Briefly, the conditions under which fertilizers were first applied to Hood River orchards were as follows. Clean cultivation was for many years the established practice; the result was, that the humus content and the available nitrogen of the soil both became very low. The physical condition of the soil underwent a marked change in that it puddled or baked easily, lacked water-holding capacity, and on hillsides was subject to erosion. Under these abnormal conditions trees failed to make a satisfactorily growth. Fruit spurs lacked vigor, and a high percentage of blossoms failed to set their fruits. Fruit was of deep color but small; yields were abnormally small.

TABLE XIII. RELATION OF YIELDS AND GROSS VALUE OF FRUIT PER ACRE (SIX-YEAR ANNUAL AVERAGE) TO USE OF NITRATE OF SODA AS FERTILIZER, NUMBER OF LIVESTOCK PER TEN-ACRE UNIT AND USE OF MANURE.

Group	Boxes per acre	Nitrate of soda					Horses and cattle		Cost—nitrate of soda	
		Pounds applied annual average		Years used	Pounds applied average per tree		Number per ten-acre unit	Percent of orchard manured annually	Per acre	Per box
		acre lbs.	tree lbs.		min. lbs.	max. lbs.				
I	**386**	33.2	.47	1.25	2.02	2.46	2.50	17.20	$ 1.55	$ 0.0040
II	**257**	34.4	.39	1.38	1.90	2.10	2.15	11.20	1.58	0.0061
III	**186**	44.0	.60	1.70	2.36	3.08	2.45	13.30	2.00	0.0110
	Value of fruit per acre									
I	**$461**	28.2	.39	1.00	1.88	2.10	2.94	10.85	1.29	0.0035
II	**290**	37.7	.43	1.56	1.89	2.34	2.06	13.30	1.73	0.0069
III	**204**	61.9	.69	1.84	2.62	3.33	1.67	7.18	2.84	0.0150
Grand Av.		**37.2**	**.49**	**1.47**	**2.11**	**2.60**	**2.37**	**13.90**	**1.71**	**0.0064**

Experimental work with nitrate of soda very quickly indicated that nitrogen was the limiting factor. When this was applied, trees took on renewed vigor. Terminal growth was good. Fruit spurs became vigorous, and a high percentage of the blossoms retained their fruits until maturity. Large, green, vigorous foliage resulted. There was a marked increase in size of fruit on fertilized trees. With Spitzenburg, however, repeated applications of nitrate of soda tended somewhat to decrease the deep red color.

When two or three successive annual applications of nitrate of soda had been made it appeared that excessive use of this fertilizer could easily be made. There was evidence to support the view that by so doing deep color in Spitzenburgs might be unduly sacrificed and possibly keeping quality impaired. There appeared to be a danger, moreover, that trees might be "thrown out of balance" in that the trees' energies would be diverted into excessive wood-growth instead of properly proportioned fruit production.

On the other hand in the experimental orchards referred to shade crops such as clover or alfalfa were introduced. The former were grown largely for turning under in order quickly to restore humus, while alfalfa was seeded with the view of keeping it in the orchard for many years. These two soil practices are, therefore, essentially distinct.

Table XIII shows the relation of fertilizer practices to yields and gross value of fruit to the acre. The striking fact brought out is that on a six-year average comparatively small amounts of nitrate of soda have been used. No apparent relation is established, that would tend to show that one group of growers secured larger returns than another group because of more or less nitrate used. As a matter of fact, Group III representing poorest averages both in yields and in value of fruit has both a minimum and a maximum average application per tree, exceeding that of Groups I and II.

TABLE XIV. RELATION OF YIELDS, SIZES, AND GROSS VALUE OF FRUIT PER ACRE (SIX-YEAR ANNUAL AVERAGE) TO PERCENTAGE OF ORCHARD CULTIVATED, COSTS PER ACRE AND BOX. (See Table XI. for labor costs.)

Group	Boxes per acre	Plowing		Harrowing		Disking		Total cost	
		Percent of orchard	Cost per acre	Percent of orchard	Cost per acre	Percent of orchard	Cost per acre	Acre	Box
I	**386**	3.30	$0.124	35.90	$0.290	25.2	$0.355	$0.769	$0.0020
II	**257**	4.60	.173	43.60	.352	18.9	.266	.791	.0031
III	**186**	1.50	.056	50.60	.408	24.5	.345	.809	.0043
	Percent four-tier								
I	**65.0**	2.00	.075	37.20	.300	19.3	.272	.647	....
II	**51.5**	3.20	.120	45.90	.370	25.4	.358	.848	....
III	**33.0**	2.50	.094	53.30	.430	23.5	.331	.855	....
	Value per acre								
I	**$461**	3.40	.128	33.30	.269	21.7	.306	.703	.0019
II	**290**	4.59	.173	55.75	.451	26.4	.372	.996	.0039
III	**204**	2.10	.079	56.50	.456	27.3	.384	.919	.0050
Grand Av.	.....	**3.10**	**.117**	**50.20**	**.406**	**25.1**	**.354**	**.877**	**.0033**

Note: The cost of rilling for irrigation is not included.

If all the nitrate of soda used were distributed over the grower's entire acreage annually the grand average for six years would be only 37.2 pounds an acre and 0.49 pounds a tree. Figures have been presented in this manner since this is a six-year average survey. It is worthy of note that nitrate, up to and including 1918, was used only 1.47 years. The minimum average of pounds applied per tree is 2.11, with a maximum of 2.60.

Livestock. The number of livestock maintained, including horses and cattle, has been figured on a ten-acre basis. The percentage of the orchard annually manured from these is also indicated. The figures show that only 13.9 percent of the land is thus treated. Differences existing between the three groups would not be sufficient to merit any conclusions with reference to this practice. The fact that an abundance of humus is furnished the soil by means of clover or alfalfa would probably tend to minimize the importance of this fertilizer. The average cost of nitrate of soda has been placed at $1.71 an acre or $0.0064 a box.

CULTIVATION

Following the cessation of clean cultivation as an annual orchard practice and the introduction of shade crops, the amount of plowing, harrowing, and disking has been very materially reduced. Table XIV shows the relation of these practices to yields, percentages of Four-tier apples, and gross value of fruit to the acre. The shade-crop method of management is such that little cultivation would be necessary or advisable at certain stages of development. Where alfalfa is seeded it is usually inadvisable to cultivate for at least two years, for the reason that the plants are small and the root system unable to stand heavy disking or harrowing such as is given older plants. The customary practice is to double disk or harrow thoroughly with a spring tooth. The aim is to kill weeds and tear out grassy sod; also to subdivide the crowns and thus thicken the stand. Where this practice is not followed, alfalfa has difficulty in becoming vigorous since grass becomes excessive. Grass also tends to take up much nitrogen needed for tree growth. Trees growing under such conditions are less responsive to applications of nitrate of soda than those growing under more favorable conditions. The table shows that for the period 1913-1918 the average percentage of the orchard plowed was only 3.1, harrowed 50.2 (once over) and disked 25.1. The average annual cost for all operations is $0.877 an acre and $0.0033 a box.

IRRIGATION

Irrigation for apple orchards in Hood River Valley has fundamental importance. Rainfall for the entire year, though ample, is not sufficiently well distributed during the summer months to permit ample tree growth and maximum production. When orchards were young, irrigation was not a serious factor. Clean cultivation served to conserve enough moisture for all requirements; however, as stated, this system of cultivation depleted soil fertility.

Since the introduction of alfalfa or clover in the orchard the moisture requirements have practically doubled. This varies according to the age of plants and method of handling. Where alfalfa is cut for hay it is evident that maximum moisture requirements prevail. The customary practice is to make at least one cutting for hay during early summer. A second cutting is often made before picking time, but the hay is not removed. The aim of such a practice is to permit organic matter to return to the soil. Thorough disking during early spring is the usual method of incorporating such organic matter within the soil. Such a practice also tends to discourage weed seed dissemination, and to form

TABLE XV. RELATION OF YIELDS (PACKED BOXES) AND GROSS ANNUAL VALUE OF FRUIT PER ACRE (1913-1918) TO TOPOGRAPHY OF ORCHARDS, NUMBER AND CHARACTER OF IRRIGATIONS, LABOR COSTS PER ACRE AND PER BOX.

Group	Yields per acre	Topography Percent of orchards				Irrigation Percent of growers Number of irrigations				Method Percent of growers			Man days per acre		Costs	
		Steep	Rolling	Steep and rolling	Level	2+	3+	4+	Average number	Rill	Flood	Rill and flood	Each irrigation	For season	Acre	Box
		%	%	%	%											
I.	**386**	4.65	11.63	4.65	11.63	...	4.6	27.8	3.53	6.66	....	26.64	.79	**2.79**	$6.50	$0.0170
II.	**257**	....	18.60	9.30	9.30	7.0	11.2	18.9	3.66	8.88	4.44	22.20	.56	**2.07**	4.82	.0187
III.	**186**	2.32	13.95	4.67	9.30	...	13.9	16.6	3.68	6.66	....	24.52	.42	**1.57**	3.65	.0196
	Value per acre															
I.	**$461**	2.77	11.08	2.77	11.08	...	...	....	4.15	7.40	3.70	14.80	.56	**2.35**	5.47	.0150
II.	**290**	....	22.44	8.31	8.31	...	...	....	3.70	3.70	3.70	37.00	.54	**1.99**	4.64	.0190
III.	**204**	2.75	8.31	11.08	11.08	...	...	....	3.58	11.10	....	18.50	.42	**1.51**	3.51	.0190

a mulch. Some growers do not cut alfalfa in the orchard, for thus the moisture requirements are greatly reduced. Since alfalfa, when allowed fully to mature, returns more plant food to the soil than when it is cut at an earlier stage of development, it seems reasonable that the practice of not cutting should afford better results.

Table XV indicates the relation of yields and value of fruit to the topography of soil, number and character of irrigations, labor requirements, and costs per acre and per box. The lands upon which orchards are located are classified as steep, rolling, steep-rolling, and level. It will be noticed that apparently the land factor is not one of great importance as far as yields are concerned, there being representatives in every class. This is not to be construed as meaning that one location is as favorable as another. Facility in irrigation, air, and soil drainage are factors of fundamental importance, usually favoring orchards on rolling land. The topography of the entire locality is of greater importance, however, than that of any individual orchard.

Number of Irrigations. The grower applies from two to four irrigations per season depending upon the rainfall, soil culture, shade crops, etc. The majority of those in Group I (yields) average more than four irrigations annually. The average number of irrigations for each group is approximately the same, varying from 3.53 to 3.68. A common method is to combine the rill and flood methods where topography will permit. Of the growers in Group I (yields) 26.6 percent employ the combined methods; in Group II 22.2 percent; and in Group III 24.52 percent.

Labor Charges. Striking differences appear under labor charges, "man days per acre" for irrigation. Therein probably lies one of the fundamental causes for differences in results. It is apparent that where the total supply of water is only four "miners inches" to the ten-acre unit, economy in application must be practiced. Such economy is obtained in careful attention to details such as the proper making of rills, the head of water used, etc. Often water is allowed to run in one part of the orchard too long. The result is a failure to irrigate the orchard with sufficient frequency and regularity to maintain uniform soil moisture. Again, an insufficient head of water permits waste near the flume and an insufficient supply to trees at the other end of the row. Proper supervision of irrigation requires very frequent inspection of factors mentioned. Group I (386 boxes) shows an average of 2.79 man days per acre per season; Group II (257 boxes), 2.07 days; Group III (186 boxes), 1.57 days. In other words, Group I spends 78 percent more time each season supervising approximately the same number of irrigations than Group III. The same point of view is well illustrated under the "Value per Acre" classification. Group I spends 2.35 days per acre; Group II, 1.99 days; Group III, 1.51 days.

SPRAYING

Spraying is a fundamental orchard practice. Much progress has been made during the past few years in methods of application, combinations, dilutions, and timeliness. This is reflected in higher percentages of Extra Fancy fruit. The most striking introduction has been the use of the "spray gun" in place of the long, cumbersome spray rod.

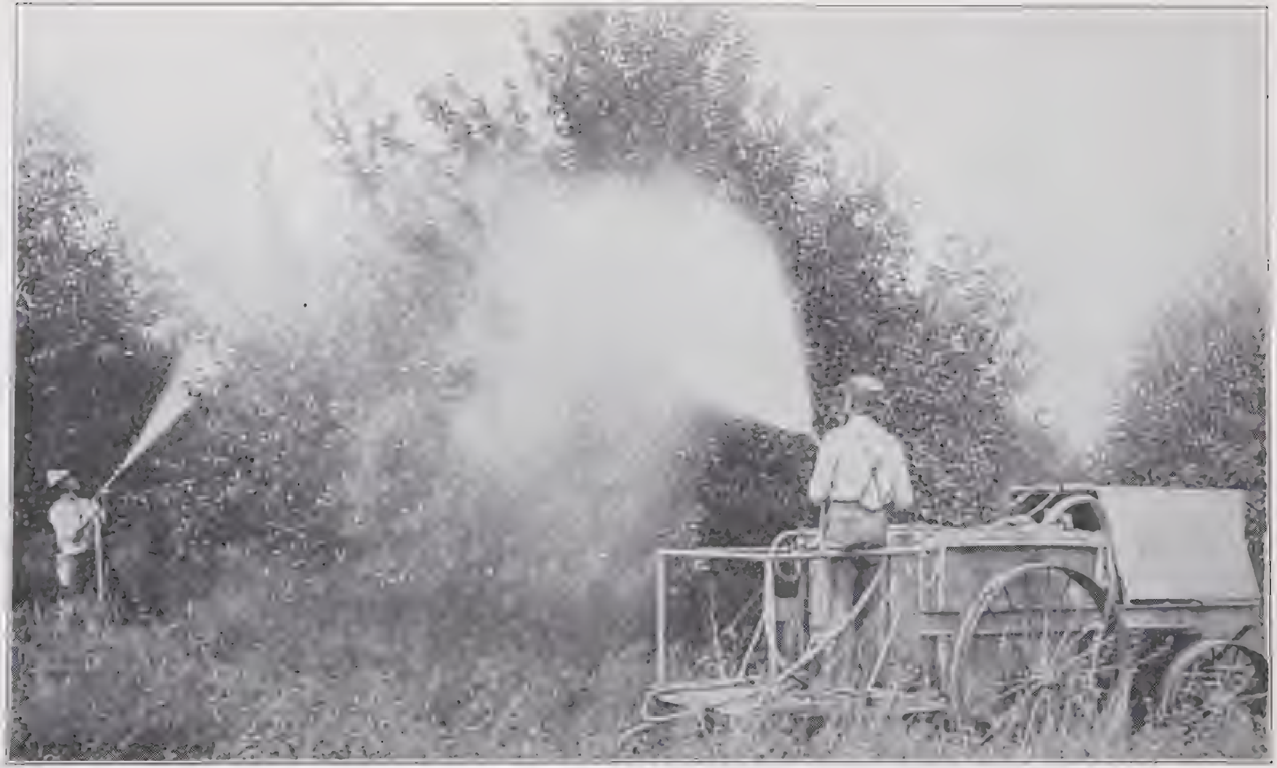

Fig. 6. Two types of spray thrown from a gun. For close-range work the broad fan-shaped spray should be employed. The tops may be covered by using the narrower form. Avoid drenching; this often occurs before the art of spraying is mastered.

—*Courtesy of Leroy Childs.*

Greater efficiency in the use of labor and material has resulted. During nearly the entire period covered by this survey the three and one-half horse-power sprayer with two spray rods was used. The same machine has now been supplanted by one "spray gun" or replaced by a larger machine, usually ten or fifteen horse-power, capable of furnishing two or three guns with a capacity of approximately fifteen gallons a minute. The spraying practice in Hood River Valley is quite uniform, practically all growers conforming to a set schedule. The 1919 spray calendar of the Hood River Branch Experiment Station is quite similar to that used in 1917 and 1918 ·and is used as a basis. This schedule admits nine different sprays, covering the possibility of having to combat practically all important insects and fungous diseases. The average number of sprays is from six to seven.

TABLE XVI. RELATION OF YIELDS PER ACRE, PERCENTAGE OF EXTRA FANCY, AND GROSS VALUE OF FRUIT PER ACRE (1913-1918 ANNUAL AVERAGE), TO NUMBER OF SPRAYS, GALLONS PER ACRE AND PER TREE ANNUALLY APPLIED, LABOR AND MATERIAL COSTS PER ACRE AND PER BOX.

Group		Gallons applied annually			Labor per acre* days per season		Costs per A.		
	Yields per acre	Per acre	Per tree	Number of sprays average	Man	Team	Labor	Material	Box†
I	386	**2015**	27.45	....	3.43	1.68	$12.72	**$30.46**	**$0.112**
II	257	**1923**	27.21	....	3.34	1.53	12.03	**29.06**	**0.159**
III	186	**1381**	20.26	....	2.35	1.07	8.45	**20.87**	**0.157**
	Extra fancy percent								
I	55.0	**2181**	29.34	6.14	....	....	.....	**32.97**	.....
II	44.9	**1653**	23.56	6.72	....	....	.....	**24.99**	.....
III	35.3	**1592**	24.00	6.25	....	....	.....	**24.07**	.....
	Value per acre								
I	$461	**1813**	26.15	....	2.72	1.38	10.24	**27.40**	**.1031**
II	290	**1981**	27.10	....	3.49	1.48	12.18	**29.94**	**.1670**
III	204	**1385**	21.00	....	2.40	1.16	8.84	**20.94**	**.1630**
Grand average	.....	**1761**	24.87	6.46	2.99	1.39	10.84	**26.62**	**.1410**

* Based on use of rods in spray control.

† Costs are based on the spray gun equivalent (3½ horse-power, one gun) of a similar outfit with rods. The latter method prevailed during a major portion of the six years covered in this survey. Labor charges include those of man, team, and machine.

Spray Calender. The first application is miscible oil, used at the rate of 8 to 100 (16 to 100 if weather is very warm and dry). The second spray is known as the delayed dormant. In this, lime-sulfur, 32 Baume degrees, is used at the rate of 1-30. This spray is for apple-scab and mildew. For brown aphis add nicotine sulfate, 1 to 1200. The third spray is applied as the blossoms are showing pink. This spray is also for fungus and mildew. Lime-sulfur is used 1 to 35. The fourth spray is a calyx application for fungus, mildew, and codling-moth. For the two former, lime-sulfur is used, 1 to 40. For codling-moth, lead arsenate paste is used 4 to 100. Powdered lead is used 2 to 100. In the fifteen-day application lime-sulfur is used, 1 to 50, for fungus and mildew, when necessary and weather permitting. This is applied usually not later than fifteen days after the calyx spray. The sixth or thirty-day application combats codling-moth and possibly green aphis or woolly aphis. Lead arsenate paste 4 to 100 or powdered lead 2 to 100 and nicotine sulfate 1 to 1200 are used. The seventh or July spray is sometimes applied to combat green or woolly aphis. Tobacco (1 to 1200) and soap (3 pounds to 100 gallons) are used. This is not a regular spray. The third codling-moth spray uses arsenate of lead in similar strength to that shown above. For anthracnose and late fungus, bordeaux mixture 3-4-50 is added. A fall application for anthracnose is made after the apples are picked. In this, bordeaux 6-6-50, winter strength, is used.

Amount of Spray Material Used. Table XVI summarizes the relation of yields, percentages of Extra Fancy fruit, and gross value of fruit per acre to spraying practices. Striking differences in amount of spray material used by the different groups is brought out. Group I (yields) shows an average of 2015 diluted gallons to the acre annually; Group II, 1923 gallons; and Group III, 1381 gallons. On a tree basis this is 27.45, 27.21, and 20.26 gallons for each group respectively. Under Extra Fancy, Group I shows 2181 gallons an acre or 29.34 a tree; Group II, 1653 an acre or 23.56 gallons a tree; and Group III, 1592 gallons an acre or 24.0 a tree. A similar relation is pointed out under "Value of Fruit per Acre."

The data presented are in harmony with the results reported by Childs.[4] In a comparative spraying test in two typical 14-year-old orchards, covering two seasons, the author reports having used an annual average of 48.6 gallons a tree in Orchard 1 and 30.7 gallons in Orchard 2. In the first case the average was 6.08 gallons a tree each spray, and 4.39 in the second. The cost of material and labor in the first case was $0.799 a tree and $0.552 a tree in the second. The apparent saving was therefore $0.257 a tree in favor of Orchard 2. These figures have been checked against net results as measured in the amount of clean fruit. Orchard 1 obtained maximum results in pest control. This has not been true with Orchard 2. In reducing the amount of spray material used its effectiveness has been reduced to such an extent that annual loss has amounted to nearly twice the total season's spraying charges.

Concretely, the second orchardist saved 24 cents a tree in spraying charges but lost 104 cents more in fruit than the first orchardist. For the second grower the additional spraying cost netted 495 percent. This principle is reflected strongly in Table XVI. Group III is credited with only 35.3 percent Extra Fancy as compared with 55.0 percent for Group I. It is apparent that the saving of $8.90 an acre annually for material will not offset this. Lower percentages of Extra Fancy are always reflected in higher percentages of culls and cookers, resulting in lower average yields of boxed fruit. Notice how this is reflected in costs per box. Group I (yields) spends $30.46 plus $12.72 or $43.18 an acre annually but only $.112 a box; whereas Group III spends $20.87 plus $8.45 or $29.32 an acre with a box cost of $0.157. The grand average cost a box for spraying is $0.141. Costs are based on the spray-gun equivalent (three and one-half horse-power, one gun) of a similar outfit with rods. Labor charges include those of men, team, and machine.

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[4] Oreg. Agri. Exp. Sta. Bul. 171, Spray Gun vs. Rod and Dust in Apple Orchard Pest Control, by Leroy Childs.

PROPPING

Table XVII summarizes pruning, thinning, and propping. These practices are very important and are more or less closely related. The amount of propping of course depends upon the amount of fruit carried by the tree, length and strength of bearing wood, and the location of the fruit. If the fruit is carried terminally at the end of long weak limbs, propping is necessary either to avoid broken limbs or bruised and scratched fruit. In nearly all cases wooden props are used for this purpose; some growers use twine, which by means of hooks fastened

TABLE XVII. RELATION OF YIELDS, SIZES, AND GROSS VALUE OF FRUIT PER ACRE (1916-1918 ANNUAL AVERAGE) TO PERCENTAGE OF ORCHARD PRUNED, THINNING, AND PROPPING, INCLUDING COSTS PER ACRE AND PER BOX.

Group		Pruning			Thinning			Propping		
		Percent of orchard pruned	Cost		Man days per acre	Cost		Man days per acre	Cost	
	Yields per acre		Acre	Box		Acre	Box		Acre	Box
I	386	78.0	$6.03	$0.0156	2.97	$6.92	$0.0180	1.08	$2.51	$0.0068
II	257	77.7	6.50	.0252	2.18	5.07	.0170	.98	2.28	.0088
III	186	48.7	4.07	.0219	1.36	3.16	.0170	.82	1.91	.0103
	Percent four-tier									
I	55.0	78.3	5.42	......	....	.....	......	....	.....	......
II	44.9	70.2	5.66	......	....	.....	......	....	.....	......
III	35.3	64.0	5.21	......	....	.....	.....	....	.....	......
	Value per acre									
I	461	73.4	6.24	.0170	2.81	6.54	.0170	.80	1.86	.0050
II	290	80.0	7.92	.0315	2.18	5.08	.0200	1.00	2.33	.0093
III	204	54.7	7.00	.0384	1.08	2.52	.0140	.75	1.74	.0140
Grand Av.	.....	60.6	5.28	.0200	1.90	4.43	.0167	.92	2.14	.0080

to certain limbs and a central limb or pole holds up the fruit in an excellent manner. In most cases, however, this practice has been discontinued because twine has been costly. The number of props will vary in number and length. Where trees are structually strong, as few as two or three wooden props may be required. Under less favorable conditions as many as ten or fifteen props a tree are required. As a rule, Newtowns require fewer props than do Spitzenburgs. This is because the trees are structually stronger and, having a green or yellow apple, require less sunlight than do colored varieties such as Spitzenburg. The customary method is to begin propping when fruit is one-half to two-thirds full size. At that time the owner distributes props by wagon throughout the orchard, then places them where needed. The placing of props requires good judgment to secure best results with as few as possible.

THINNING

Thinning is another fundamental orchard practice requiring thoroughness, timeliness, and good judgment. There are several aims which the grower usually has in mind when doing this work. One is, that such a practice tends to promote annual bearing; in other words, removing fruit entirely on some spurs will tend to cause such spurs to fruit during the following year rather than to overbear one year with little or no fruit the next year.

Data compiled at different experiment stations throw serious doubt upon this conclusion. At the West Virginia Experiment Station[5] thinning experiments were conducted for a number of years. Thinning did not promote annual bearing and where over-thinning was practiced yields were reduced.

Both Yellow Newtown and Spitzenburgs are alternate bearers as far as individual fruit spurs are concerned. The spur blooms and produces fruit one season but as a rule a fruit bud is not formed on the same spur during the same season. Vigorous spurs, favorably located, will during the following year produce a fruit bud and again fruit with one barren year intervening. There are many spurs which do not fruit more often than every three or four years. In case a very high percentage of buds bloom the one year, an undesirable condition is brought about. Such trees tend to be irregular since only a comparatively few spurs remain to bloom and bear fruit during the following year. Such a habit is objectionable in that heavy thinning is required to produce marketable fruit one year without the prospect of much fruit on the following year.

When this habit and the limitations accompanying the benefits from thinning are understood the natural tendency is to leave as much fruit as possible. Up to a certain limit this is justifiable and a good practice. It is desirable to leave as much fruit as the tree is capable of carrying and maturing in good marketable form. When an excess load is allowed, trees break down unless well propped and the sizes run small. Spitzenburgs vary in their habits. In some orchards they are decidedly alternate bearers, but in others a well-distributed bloom occurs each year. This results in minimum costs for thinning.

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[5] W. Va. Exp. Sta. Bul. 162, Five Years Investigations in Apple Thinning, by E. C. Auchter.

Thinning is usually done during the latter part of June or the early part of July. Previous to this time the "June drop" has occurred, and scab or insect injury is apparent. Thinning then can be directed against malformed apples or those injured in other ways. Men, women, and large children engage in thinning.

PRUNING

Pruning is directly related to spraying, thinning, and propping. It may be so done as to facilitate work in either of the other practices. Many growers do their heavy pruning previous to a heavy crop. With Spitzenburgs this consists of considerable heading back to hold in check excessive terminal growth. With Newtowns thinning out is more the general rule since this variety tends towards lateral growth. A combination thinning and heading is given both varieties as occasion may demand. Pruning directly aids thinning since many fruit buds can be removed in one operation, but considerable differences of opinion exist with reference to methods of pruning. Many are inclined to over-prune and thus reduce the bearing area. It is obvious that the grower must have three or four times as many spurs as fruits if he is successfully to combat irregular bearing. On the other hand, some growers go to the

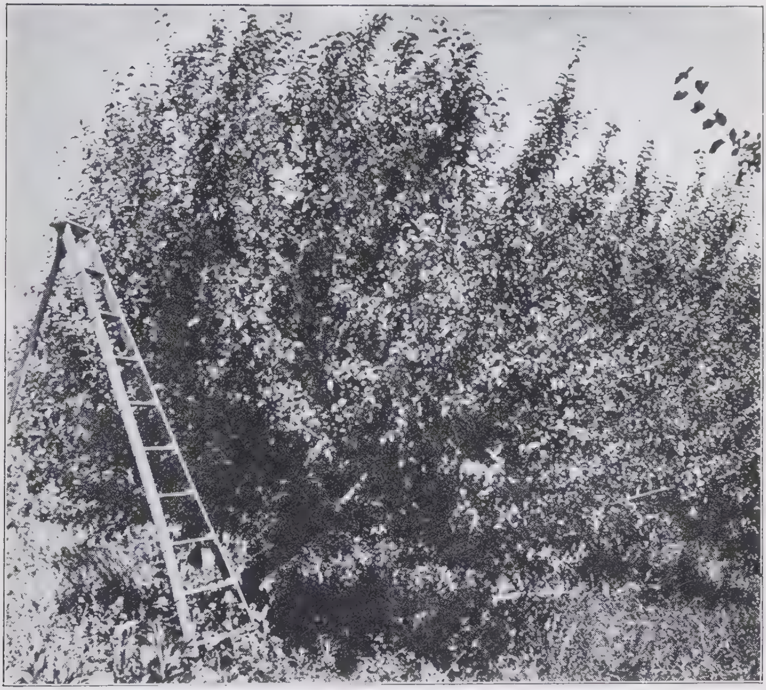

Fig. 6. One reason for cull apples. Tree greatly in need of pruning to permit sunlight to enter and facilitate proper spraying. Such trees produce small apples of poor color, often wormy.

other extreme in failing to prune enough. No set rule can be laid down which will cover all cases. Generally speaking, one may safely avoid heavy pruning while the trees are young and vigorous, especially thinning out. This would be true with yellow or green apples. Red apples would need at least a light thinning out. One grower of Newtowns fifteen years old who had very large yields on a six-year average practically did no pruning on his trees between the ages of six and twelve years with the exception of removing a few large lower limbs which interfered with cultivation. With a maximum fruit-spur system and vigorous trees very large yields have been secured. Such a plan has not, however, been without its disadvantages. Fruit spurs in the lower portion of the trees have become weakened through excessive shading and do not today function vigorously. Thus the tendency is for fruit wood to extend further and further out on the main limbs where it is less easily thinned, sprayed, or propped. This is a condition into which many of the older orchards have fallen, that of having long barren areas in the lower portion of the tree devoid of fruit spurs. It is difficult, if not actually impossible to restore such fruiting wood in the area mentioned, chiefly because any rational plan of pruning is too far removed from the area to be influenced. Unusually heavy pruning removes practically all new, thrifty, bearing wood and promotes an excess of "suckers" which in turn do not come into fruiting or may produce a few weak spurs after possibly several years of waiting.

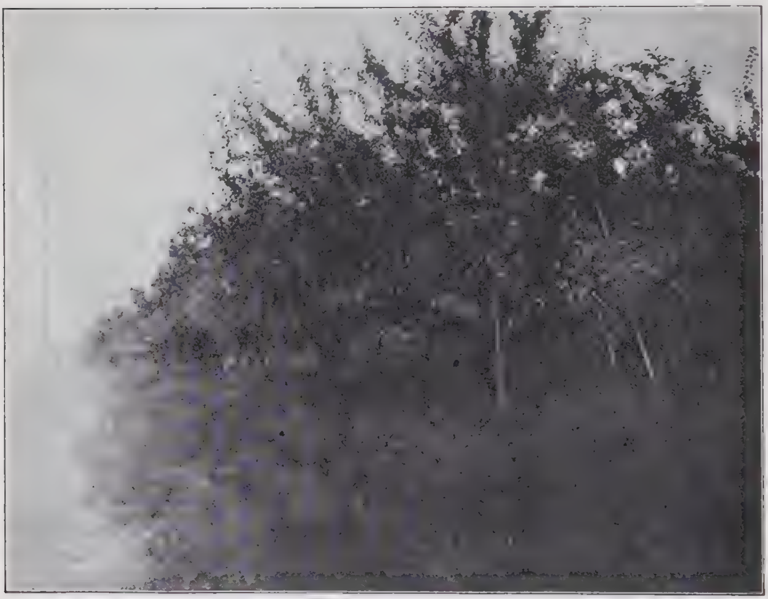

Fig. 7. Spitzenburgs well pruned. Such trees are more easily propped, sprayed, and thinned, resulting in more fruit of higher quality. Alfalfa is here employed as a "shade crop."

For older trees the data brought out in Table XVII are very consistent with well-established recommendations of able horticulturists. The more nearly the grower approaches annual pruning the more satisfactory and uniform have been results. Group I (yields) averages 78 percent of the orchard annually pruned; whereas, Group III averages only 48.7 percent. Such regularity of pruning as is seen in Group I is likewise supported from a strictly scientific point of view. It is a well-established fact that the greatest influence of pruning is always near the cut. In other words, a large number of small cuts (local pruning) removing in the aggregate the same amount of wood as a few large cuts (bulk pruning) have a better and more uniform influence than the latter practice. Annual pruning more closely approximates local pruning, whereas, biennial pruning approximates bulk pruning in that less wood need be removed at one time. The influence of the first practice is more steady and uniform. Such a practice would not necessarily eliminate the possibility of doing more heavy pruning before a heavy crop year.

Greater thoroughness or regularity in pruning has been accompanied by more time spent in thinning. This fact might seem inconsistent with the idea that pruning saves in thinning costs, but not necessarily so. A great deal of haphazard, hit-or-miss thinning is done in some orchards. Such methods or labor standards are not to be compared with more consistent, thorough work. Furthermore, orchards in Group I having a greater average yield would naturally require more time in thinning than orchards in Group III, which have less than 50 percent as much boxed fruit as Group I. Trees in Group III often have a poor bloom or poor "set" of fruit necessitating little or no thinning.

The foregoing facts are strongly supported in the figures presented in Table XVII. Group I (yields) averages 2.94 man days an acre in thinning; Group II, 2.18 days; Group III, 1.36 days. As will be noted, although Group I spends more per acre in both pruning and thinning, the costs per box are much less than the other two groups in the former instance and approximately the same in the latter.

Likewise Group I (yields) calls for more time in propping than the other orchards. The average man days an acre is 1.08 as compared with 0.98 for Group II and 0.82 for Group III. Similarly, costs to the box are $.0068 for Group I; $.0088 for Group II; and $.0103 for Group III.

Relations between the different groups similar to that given above are noted under "Percent Four-tier" and "Value per Acre." The grand average percentage of the orchard annually pruned is 60.6 at a cost of $5.28 an acre and $.020 per box; thinning 1.9 man days an acre costing $4.43 an acre and $0.0167 a box; and propping 0.92 man days an acre, costing $2.14 an acre and $0.008 a box.

SUMMARY

(1) This bulletin is a six-year summary of apple-orchard economics and practices in Hood River Valley. The period covered extends from 1913 to 1918. Studies of two distinct three-year periods are also included; namely, 1913-1915 and 1916-1918. The former period is characterized by lower yields and grades of fruit, together with less efficiency in practices than was true of the latter period. Soil practices and irrigation and spraying programs have undergone considerable changes, resulting in greater yields and cleaner fruit.

(2) The general orchard average in packed fruit was 215 boxes annually for the period 1913-1915 and 314 boxes for 1916-1918. The six-year average is 264 boxes. The six-year average yield for the following varieties is also noteworthy; Delicious, 710 boxes; Baldwin, 504; Red Cheek, 500; Black Twig, 473; Ortley, 400; Winter Banana, 385; Jonathan, 376; Arkansas Black, 322; Spitzenburg, 256; and Newtown 238 (Table I). Culls and cookers are not included.

(3) A wide variation in yields is recorded. Of the different orchards 25.0 percent (Group I) have a six-year annual average of 386 packed boxes; 37.5 percent (Group II), 257 boxes; and 37.5 percent (Group III), 186 boxes. Likewise, eight of the more important varieties are similarly rated (Table II).

(4) The grand average Extra Fancy for the Hood River Valley is 34.6 percent (1913-1915) and 47.0 percent (1916-1918). The six-year average is 40.8 percent (Table III). The average percentage Extra Fancy for those orchards included in the survey is 39.6 percent (1913-1915), 49.8 percent (1916-1918), with a six-year average of 44.7 percent (Table IV).

(5) The grand average Four-tier for the Valley is 59.6 percent (1916-1918). The six-year average is 53.6 percent (Table III). The average percentage Four-tier for the orchards surveyed is 56.6 percent (1913-1915) and 44.2 percent (1916-1918), with a six-year average of 50.4 percent (Table IV).

(6) Orchards are rated according to their six-year record in producing a high or low percentage of Extra Fancy and Four-tier size fruit. Group I, representing 23.1 percent of the growers, averages 55.0 percent Extra Fancy; Group II, representing 50.0 percent of the growers, averages 44.9 percent Extra Fancy; 26.9 percent of the growers average 35.3 percent Extra Fancy (Table V).

(7) Similarly orchards producing 65.0 percent Four-tier fruit, representing 17.8 percent of the growers, are classed in Group I; 62.9 percent of the growers are found in Group II, with an average of 51.5 percent Four-tier; and 19.3 percent of the growers are found in Group III, with an average of 33.0 percent Four-tier (Table V).

(8) Delicious, Winter Banana, Arkansas Black, Winesap, Spitzenburg, and Newtown have relatively the highest average record of net prices received on a six-year basis, Delicious standing first with $1.808 a box for Four-tier, Extra Fancy. A complete summary of prices is given in Table VI and Fig. 1.

(9) Orchards are rated according to the gross annual value of packed fruit to the acre (1913-1918). Group I, comprising 24.4 percent of the growers, shows a value of $461.00; Group II, 40.9 percent of the

growers, shows $290.00; and Group III, 34.7 percent of the growers, shows $204.00. The grand average acre value is $304.00 an acre or $1.18 a box. Ten varieties are similarly classified (Table VII).

(10) The relation of gross value of fruit to percentages of Extra Fancy, Four-tier, sizes and yields is tabulated. Yields are shown to be the greatest factor. High yields and high values are consistent factors, as is likewise true of small yields and low values (Table VIII).

(11) The average age of apple trees covered in this study was 15.6 years in 1918; the average acreage of bearing trees is 17.94, non-bearing, 4.05; the average number of trees per acre 71. Highest yields (Group I) come from orchards averaging 10.01 acres. Lower yields (Groups II and III) are associated with larger acreages (Table IX).

(12) The prices of both labor and materials have been unstable factors during the period covered in this survey. Average common labor is placed at $2.33 per day; lime-sulfur and miscible oil at $14.16 and $34.80 per 100 gallons respectively (Tables XI and XII).

(13) Nitrate of soda has in general been used lightly, the grand average being 37.2 pounds an acre and .49 pounds a tree. No striking relations between the different groups are indicated. Horses and cattle do not occupy a prominent position in respect to orchard management (Table XIII).

(14) The percentage of the orchard annually plowed, harrowed, and disked as related to group averages is studied. Comparatively little plowing has been done, having been largely replaced by harrowing and disking in early spring. No striking differences between the groups is brought out (Table XIV).

(15) Topography of the orchard has not been a factor of great importance as far as yields are concerned. Striking differences are noted with reference to irrigation. Orchards with high average yields (Group I) employ 2.79 man days an acre a season as compared with orchards of low yields (Group III, which employ 1.57 man days). Approximately the same number of irrigations a season are given by orchards in each group. Herein lies one limiting factor in production (Table XV).

(16) Spraying practices differ widely. Group I (yields) applied 2015 gallons an acre annually as compared with only 1381 gallons for Group III. Similar differences are noted under a study of Extra Fancy and gross value of fruit. This is another limiting factor in production (Table XVI).

(17) Pruning, thinning, and propping are studied (Table XVII). Orchards in Group I (yields) average 78 percent of the orchard annually pruned as compared with 48.7 percent for Group III.

(18) The survey as a whole standardizes orchard management upon the basis of merit. It points out striking differences in management as related to high or low standards of success. Its most hopeful feature lies in the fact that remedial steps may be taken by many orchardists to better their condition.

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Eastern Oregon Branch Station

Growing Steers

By
E. L. POTTER
and
ROBERT WITHYCOMBE

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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FEED LOTS AT EASTERN OREGON BRANCH EXPERIMENT STATION

SUMMARY

Methods of wintering growing steers not only determine the gains made during that period, but also influence in a large degree, the gains made during the grazing season, as well as the age, final weight, and quality of the cattle when ready for market.

Steers that have been wintered lightly as calves and yearlings, do not weigh as much when finished as do those that made larger gains during the winter feeding period.

Fat calves or yearlings from the winter feed lots made less gains than thinner cattle during the growing season.

Growing steers making large gains during the winter, lose practically one-half of this advantage gained over the lighter fed steers, owing to the small gains made during the grazing season.

Young growing steers should hold their own during the winter, but large gains during the winter feeding period are neither necessary nor desirable unless they can be made economically.

Gains made on grass are always cheaper than those made on winter feeds; hence growing steers should be kept on grass for the longest possible time during the grazing season.

The feeding of grain is necessary in the production of baby beef, but is not recommended with growing steers that are to be turned out on grass.

In sections where plenty of range is available for grazing purposes marketing steers as baby beef is less profitable than marketing them as two- or three-year olds.

Alfalfa hay is the standard ration for wintering cattle and the one with which all other rations are compared.

Silage alone can be used as a winter ration, but better results are obtained when silage is fed in connection with some protein supplement, such as alfalfa hay or cottonseed cake.

Straw supplemented with cottonseed cake, with or without silage, or with silage alone, can be used for wintering purposes, in cases of emergency, with economic results.

Growing Steers

The object of these tests was to determine economical methods of growing beef steers, both as calves and yearlings, using common feeds for winter rations, grazing on the range during summer months and on stubble and meadow pastures during the fall. A complete record was kept of feeds and gains for summer, fall, and winter periods.

Three distinct and separate tests were conducted, although all three were along similar lines. The first test began December 22, 1916, with six lots of twelve weanling calves each. The various lots were sold when ready for market. One lot was sold for baby beef at the end of six months, two lots were sold a year later, while the three other lots were on test for 2 years and 2 months, when the steers, at the time of sale, were almost three years old. In the fall of 1917 a second test with five lots of twelve calves each was started and in the fall of 1918 a third test, with five lots of twelve calves each, was also started.

All of the cattle were wintered in open feed lots without sheds, as shown in the frontispiece. They were watered from a stream, which was run through the lots in a board flume, and which was clean and free from ice. Each lot was supplied with straw from time to time for bedding.

During the grazing season all the lots in each test were grazed together on the same range with a view to determine the effect of various methods of wintering upon the gains made on grass the following spring, summer, and fall. Early grazing was obtained on the station farm and from rented bunch-grass pastures. Summer grazing was in fenced bunch-grass pastures and on the National Forest. In the fall the cattle were pastured on hay meadows and stubble fields at the station farm. They were usually kept on fall pasture until quite late, but as the season advanced the pasture was supplemented with a little hay, usually odds and ends, tops and bottoms of stacks.

The cattle were usually wintered for two winters—that is, as calves and as yearlings—on the rations indicated; and those that were not ready for market by the beginning of the third winter were given a full ration of hay and silage and thus fattened for market as rapidly as possible. Most of the lots were marketed when in condition to sell at or near the top in the Portland market, but none of them were good enough to bring a premium.

PLAN OF TEST NO. 1

The calves used in this test were average stock calves. They were of mixed breeding but did not show much indication of dairy blood.

Method of Feeding. Lot 1. Waste alfalfa from the steer fattening lots the first winter and a limited ration of good alfalfa the second winter.

Lot 2. All the alfalfa hay they would eat during both winters.

Lot 3. All the alfalfa hay they would eat with half as much grain as was consumed by Lot 4.

Lot 4. All the alfalfa hay they would eat and also all the rolled barley they would eat for two winters.

Lot 5. The same as Lot 4 except that they were sold as baby beef at the end of the first winter.

Lot 6. All the straw they would eat and 2 pounds of oil meal or cottonseed cake per day. They were given a little grain at the start to teach them to eat the cottonseed cake.

The first summer all the cattle were grazed together on the open range west of La Grande. The range was poor and the cattle scattered badly. The second year they were pastured in a fenced range rented from Walter M. Pierce. This is usually a good bunch-grass pasture but the season was dry and the cattle did not do extra well.

PLAN OF TEST NO. 2

The calves used in this test were an exceptionally good lot of well-bred Herefords, purchased from Walter M. Pierce of La Grande. These were better in quality, breeding, and uniformity than the average run of range calves.

Method of Feeding. Lot 1. Alfalfa hay, silage, and grain; all they would eat.

Lot 2. Ten pounds of silage and all the hay they would eat.

Lot 3. Ten pounds of silage, one pound of cottonseed cake, and all the straw they would eat.

Lot 4. Two pounds of cottonseed cake and all the straw they would eat.

Lot 5. Ten pounds of silage and all the straw they would eat.

During both summers all lots were grazed in a fenced bunch-grass pasture.

PLAN OF TEST NO. 3

The individuals used in this test were about an average grade of calves and were purchased in small lots from various owners.

Methods of Feeding. Lot 1. All the alfalfa, silage, and grain they would eat.

Lot 2. Ten pounds of silage and all the alfalfa they would eat.

Lot 3. All the alfalfa they would eat.

Lot 4. All the silage they would eat.

Lot 5. Two pounds cottonseed cake and all the silage they would eat.

During the summer all lots grazed on the National Forest.

VALUATION OF FEEDS AND METHOD OF FIGURING COSTS

The time covered by these tests included not only the period when we were engaged in the European War, but also some pre-war and post-war periods. Due to the variability in both livestock and feed prices during this period a record of the actual cost of any of these lots would be of little value at the present time. An arbitrary scale of prices, therefore, has been used in preparing the cost charts of this bulletin.

Pasture	50c and $1.00 per month
Alfalfa hay	$8.00 per ton in the stack
Silage	$5.00 per ton
Straw	$1.00 per ton in the stack
Grain	$25.00 per ton
Cottonseed cake	$50.00 per ton

Labor of winter feeding 3c per head per day.

These prices are probably a fair average of prices prevailing at the present time, and the stockman in looking over these figures can easily make the allowances necessary for any difference there may be between the prices charged and the prices on his own farm. The prices and costs, in fact, are given only as a matter of convenience, in order that the reader may more easily estimate probable costs under his own conditions. In quoting alfalfa at $8.00 it is not the intention to assert that the actual price of alfalfa is, or should be, or even will be, $8.00. It is simply an arbitrary price used in calculating cost charts.

Many factors enter into the problem of wintering, but the final success of the operation is largely determined by the final cost of the cattle, including interest, labor, and losses, and the quality of the finished beef. Since, from the standpoint of the Western market, there was not a great difference in the final quality of the beef of the different lots, we will first consider these various methods of wintering from the standpoint of cost per 100 pounds gain based upon the arbitrary prices of feed and pasture listed. Every change in feed and pasture prices necessarily must result in a change in the cost of beef.

Pasture. The cost of grazing, including necessary riding and salting, is figured arbitrarily in one case at 50 cents a month and in the other at $1.00 a month, in order that the reader may see what influence this change in price has upon the final cost of the cattle. The average cost of pasture has been about $1.00 a month, but cattle at the present market prices can hardly be expected to meet such a charge for pasture unless the pasture is exceptionally good.

Hay. The cost of hay and pasture is the key to the cost of beef. It is generally assumed that under normal conditions the price of one hundred pounds of beef on the farm and the price of one ton of hay in the stack should be about the same. It is interesting to note, therefore, in these tests how the final cost of the gains compare with $8.00 hay.

Grain and Cottonseed Cake. The price of grain was set at $25.00 a ton and of cottonseed cake at $50.00 a ton, since these prices not only represent about the present market, but are apparently fair in proportion to the prices put on hay and silage.

Straw. The straw, of course, has no established market value and since it is entirely a by-product of grain growing, the cost of production is not often considered. A value of $1.00 a ton in the stack, however, seemed fair enough, and to this is added the cost of feeding.

Silage. The price of silage was estimated at $5.00 a ton, based upon its approximate cost of production as compared with hay at $8.00; that is, there is about the same margin to the producer in silage at $5.00 as in hay at $8.00. The silage used in these tests was largely corn, and peas and bald barley. The silage was all of good quality, but the corn usually was frosted somewhat before siloing. There was but little silage made from well-matured corn, and no sunflower silage.

Labor. The charge for labor of winter feeding at three cents a day is merely an estimate as to what, in our judgment, the cost would be under ordinary ranch conditions. It is estimated that under most farm conditions one man with a team will care for 200 head of cattle.

Interest and Insurance. Interest is figured on the entire livestock investment at 8 percent, the rate generally paid for money invested in cattle. Three percent is allowed for insurance. The cattle were not insured with any insurance company, but the actual loss was about 3 percent a year, which seems about an average loss for growing cattle. Most of the experimental lots escaped with no loss, while others lost as much as three out of the twelve head. There was nothing to indicate, however, that the method of feeding had any bearing upon the losses, and therefore, in order to apportion these losses the amount of feed consumed and the gains made are figured only for the cattle that lived through the entire time of the test and a charge of 3 percent per annum is made against all the cattle in order to rate the losses equally among the various lots. Interest and insurance are charged on the initial purchase price of the calves for the entire test. Feed and labor charges,

TABLE 1. GAINS AND COSTS OF GAINS

Feed prices

Hay	$ 8.00 per ton	Cottonseed cake	$50.00 per ton
Silage	5.00 per ton	Winter labor	3c per head per day
Straw	1.00 per ton	Interest	8%
Grain	25.00 per ton	Average annual loss	3%

Test No. 1	Waste or light alfalfa	Alfalfa	Half grain	Full grain	Full grain baby beef	Straw and 2 lbs. c.s.c.
Initial weight	505.20	505.20	502.50	502.50	502.50	502.50
Final weight	1255	1343	1058	1117	798	1256
Total gain	753	841	555	614	295	753
Days on test	805	805	500	500	182	805
Daily gain	.935	1.044	1.11	1.23	1.621	.95
Cost per 100 lbs. gain with pasture at $1 per month	$8.58	$9.03	$10.41	$10.87	$10.97	$8.34
Cost per 100 lb. gain with pasture at 50 cents per month	7.35	7.93	9.80	10.31	10.72	7.12

Test No. 2	Alfalfa silage and grain	Alfalfa and silage	Silage straw and 1 lb. c.s.c.	Straw and 2 lbs. c.s.c.	Straw and silage
Initial weight	544	544	544	544	544
Final weight	1175	1258	1145	1168	1148
Total gain	631	714	601	624	605
Days on test	460	701	701	701	701
Daily gain	1.372	1.018	.857	.890	.863
Cost per 100 lbs. gain with pasture at $1	$9.16	$8.33	$7.61	$7.12	$7.04
Cost per 100 lbs. gain with pasture at 50 cents per month	8.61	7.12	6.18	5.74	5.61

Test No. 3	Alfalfa, silage and grain	Alfalfa and silage	Alfalfa	Silage	Silage and 2 lbs. c.s.c.
Initial weight	489	489	489	489	489
Final weight	1065	1272	1240	1187	1308
Total gain	576	783	751	698	819
Days on test	454	740	740	740	740
Daily gain	1.269	1.058	1.015	.943	1.107
Cost per 100 lbs. gain with pasture at $1 per month	$8.84	$8.52	$8.71	$9.49	$9.50
Cost per 100 lbs. gain with pasture at 50c per month	8.13	7.46	7.02	8.31	8.50

however, were a gradual accumulation throughout the test, starting with nothing and gradually increasing as more feed and labor were invested. Interest and insurance, therefore, are charged on feed and labor for only one-half the time of the test. As stated before, the calves for these tests were purchased as weanlings; hence this publication does not deal in any way with the actual cost of production prior to weaning.

It should always be borne in mind that the final cost per hundred pounds gain, as indicated in the various tables, includes interest and labor charges, and that if, for instance, the lot of steers which cost $7.93 per hundred pounds had been sold for that figure the owner would have made 8 percent interest on his investment for both cattle and feed as well as the price for his labor and the quoted price for his feed and pasture.

A statement of weights, gains, and costs, with pasture at both 50 cents and at $1.00 a month, are given in Table I. While this table presents a rather formidable array of figures it is hoped that the reader will study it carefully.

WINTER FEEDS

Alfalfa. Alfalfa is of course the standard ration with which all others are compared. Cattle wintered on a full ration of $8.00 alfalfa and summered on grass at 50 cents a month put on gains at a cost of $7.93 in the first test and $7.62 in the third, including all interest and labor. When the pasture charge was $1.00 a month the cost was $9.03 in the first test and $8.57 in the second. It seems, therefore, that the old rule of valuing one ton of hay in the stack at the price of one hundred pounds of beef is about correct, provided the pasture charges are not too high. Unfortunately, however, many cattlemen have invested in pasture or range lands at prices which make the grazing charges excessive, so that it is often impossible to produce cattle for $8.00 a hundred on $8.00 hay. There is, of course, a good deal of open range and cheap pasture in Oregon in which the average charge per month throughout the season is 50 cents or less, but as a general rule, the gains made under such conditions are less than those obtained in these tests. In figuring cost of pasture, the entire season when the animals are not on hay should be considered and not merely the late spring and early summer when grass is cheapest and most abundant.

In the tests where alfalfa was used as the winter ration, calves consumed an average of 20 pounds daily when given all they would eat and made a gain of 1.14 pounds. The same cattle a year later as yearlings, coming twos, were given an average of 26 pounds a day and made a gain of 1.21 pounds.

Grain. The feeding of grain to young growing steers is not a general practice among livestock men, excepting in cases where baby beef is produced. The object of including this method of feeding in the tests at the Union experiment station was primarily to determine the practicability of forcing the weanling to the earliest possible maturity, noting the effect of such feeding upon the gains made on grass during the grazing season as compared with those made by cattle fed during the winter months on less expensive rations, and also to test the advisability of marketing cattle either as baby beef or as two-year-olds.

In the first test it will be noted that the cost of gains with lots fed grain was much larger than in the lot fed alfalfa hay, the difference ranging from $1.38 to $1.94 where the pasture was charged at $1.00 a month, and the spread is still greater with the cheaper pasture. The grain-fed cattle were sold at an earlier age than the hay-fed cattle; but considering the cost figures, it will be readily seen that the only chance for the grain-fed cattle to pay out would be in their superior quality and higher selling price. Lots 3 and 4 were sold at an age of approximately two years; and while they seemed to be a better grade of cattle than those commonly appearing on the Portland market, they did not bring a premium. Cattle in Lot 5 were sold as baby beef at the age of 13 months. These were not as heavy as they should have been and not fat enough to bring the top price on the market. They failed to take on a fill at the Stock Yards, and in their ragged appearance were really not wanted by the buyers.

In the second test only the first lot was fed grain. They were sold at the end of the second winter at an age of approximately two years, but in general appearance were not much better cattle than those in other lots sold about 8 months later. The cost, as will be noted, was considerably higher than the alfalfa and silage lot and very much higher than the lots fed straw in various combinations.

Test No. 3 was the only one in which the grain-fed lots showed up to any advantage. The cost was about the same as the alfalfa-and-silage or alfalfa-fed lots where the pasture was charged at $1.00 a month but where the pasture was charged at 50 cents a month the grain-fed lot was the more expensive, which was possibly due to the fact that they did not get the benefit of a third summer on grass. It will be noted that the alfalfa was valued at $8.00 a ton and the grain at $25.00 a ton—a ratio of approximately 1 to 3. In our work with fattening steers, as reported in Station Bulletin 174, it was found that for fattening purposes one pound of barley had approximately the same value as three pounds of hay. In the case of wintering calves and yearlings, however, this rule apparently will not apply, and the grain has relatively less value than for fattening purposes, due to the fact that in wintering the greater gains made by the use of grain are partially lost through the lesser gains made on pasture the following summer. On the other hand, with fattening steers the cattle go direct from the feed lots to market and thus lose none of the added advantage that comes from grain feeding.

Table II shows the daily winter rations and winter gains for the various lots fed on grain. These lots were given what rolled barley they would clean up readily but no attempt was made to crowd them to the absolute limit on grain. They were encouraged to eat all of the alfalfa possible. As noted above, cattle in these grain-fed lots were ready for market at the end of their second winter, hence spent only one summer on grass after being weaned. It would seem an advantage to market the cattle at this early age, but it is rather doubtful if this is true, since two-year-old steers ordinarily make cheap and profitable gains on grass.

The chief drawback to the practice of feeding grain to growing steers lies in the fact that the major portion of the gains must necessarily be made on expensive feeds and the animal does not have the opportunity to take advantage of the cheap gains usually made while grazing during the summer months. Then again most cattlemen usually have more range for grazing purposes than they have grain and hay for winter feeding.

TABLE II. DAILY FEED AND DAILY GAINS OF CALVES AND YEARLINGS ON VARIOUS GRAIN RATIONS

	Calves			Yearlings		
	Daily ration		Daily gain	Daily ration		Daily gain
All the alfalfa and rolled barley they would eat	Alfalfa	18.0	1.76	Alfalfa	25.0	2.05
	Grain	6.7		Grain	8.5	
All the alfalfa they would eat and a half ration of rolled barley	Alfalfa	21.0	1.61	Alfalfa	29	1.692
	Grain	3.3		Grain	4	
All the alfalfa, silage and rolled barley they would eat readily, average of two tests	Alfalfa	11		Alfalfa	17	
	Silage	10	1.90	Silage	15	1.58
	Grain	5		Grain	6	

Silage. Knowing that cattle made both desirable and economical gains while on grass during the grazing season, it was believed possible that they might make satisfactory gains during the winter-feeding period on some succulent feed such as silage. Silage as a rule is made from plants which are low in protein, and hence in most silages there is a protein deficiency. The protein content of the silage can be increased somewhat by using such crops as peas, sweet clover, and alfalfa in various mixtures for silage purposes. A low protein content in silage is not objectionable when the silage is fed with alfalfa hay, but when fed alone or with straw a low protein content becomes quite a factor, since in order to get satisfactory gains this deficiency in protein must be made up by the use of some expensive high-protein feed like oil-cake or cottonseed cake. Table III gives the analysis of two different silages fed at the station during the winter of 1920-21. The silage used in these three tests was largely made from immature corn.

TABLE III. ANALYSIS OF CORN SILAGE AND PEAS AND BARLEY SILAGE

	Water	Dry matter	Ash	Crude protein	Ether extract	Crude fiber	N. free extract	Acid
	%	%	%	%	%	%	%	%
Corn silage	76.56	23.44	1.90	2.15	0.48	6.03	12.89	2.01
Peas and bald barley silage	63.71	36.29	3.00	5.14	1.18	7.37	19.60	1.55

In the third test in Lots 2 and 3 a direct comparison of alfalfa alone and alfalfa and silage is made, in which the alfalfa and silage produced a slightly larger gain for the entire test and at about the same cost of gain, with silage valued at $5.00 and hay at $8.00. It will also be noted that the silage was a little the more expensive with pasture at $1.00 a month and a little less expensive with pasture at 50 cents a month. This is due to the fact that the alfalfa-and-silage-fed cattle made a little larger gains in winter and consequently a little less gain in summer than did the alfalfa-fed cattle. It is possible that if the alfalfa and silage had been fed in amounts somewhat smaller than all that the animals would eat, a better showing would have been made. It seems fairly safe to assume, however, that where silage is fed with alfalfa as compared with alfalfa alone, the silage is worth about $5.00 when the alfalfa is worth $8.00 a ton.

In view of the fact that most silage is deficient in protein the best results are not expected when fed alone but rather when fed in combination with other feeds rich in protein. This idea is borne out by the results of Lots 3, 4, and 5 in the third test. The cattle wintered on silage alone made less gains and cost more money than those wintered on alfalfa. Where the protein deficiency of the silage was made up by the addition of 2 lbs. of cottonseed cake, as in Lot 5 of the third test, exceptionally good gains were made. The cattle in this lot were especially good; the record shows, however, that the cost of the cottonseed cake added to the cost of the silage made the final cost of the gains decidedly higher than where the silage was fed with alfalfa.

The possibilities of silage as a supplement to straw are shown in the second test, in which straw and silage in Lot 5, and straw and silage with the addition of 1 pound of cottonseed cake in Lot 3, made fair gains at a cost decidedly less than alfalfa and silage or alfalfa, silage, and grain. These cattle made very little gain in the winter but large gains in the summer; and it was the exceptionally large summer gains made by Lot 5 wintered on straw and silage alone that made this lot show up so well. The cattle in this lot never reached the degree of finish attained by those in the other lots. While they were of good weight, they remained rather rough throughout the entire test. The results of this one test indicate that the 1 pound of cottonseed cake used in connection with the ration in Lot 3 was not of much value, but we wish to conduct further tests before making any definite statements on this point.

Table IV shows the daily winter rations and winter gains made by the various lots on corn silage and on peas and bald barley silage. It will be noted that some of these lots made very poor gains, but the lots making poor gains in the winter usually made very good summer gains.

TABLE IV. DAILY FEED AND DAILY GAINS OF CALVES AND YEARLINGS ON VARIOUS SILAGE RATIONS

	Calves			Yearlings		
How fed	Daily ration		Daily gain	Daily ration		Daily gain
Silage limited. All alfalfa they would eat	Alfalfa Silage	16 10	1.30	Alfalfa Silage	23 15	1.39
All they would eat	Silage	32	.43	Silage	47	1.20
Silage limited. All straw they would eat	Straw Silage	11 10	.16	Straw Silage	21 15	–.09
Silage and c. s. c. limited. All straw they would eat	Straw Silage c. s. c.	11 10 1	.78	Straw Silage c. s. c.	21 15 1	.49
All silage they would eat. 2 lb. c. s. c.	Silage c. s. c.	32 2	1.20	Silage c. s. c.	47 2	1.55

When determining the amount of silage to feed, we may figure that every pound of silage fed will reduce the consumption of hay nearly one-half pound. The addition of one or two pounds of cottonseed cake to straw or silage apparently does not reduce the consumption of roughage.

Straw. Cattle wintered on straw and silage and grazed during the summer months on good bunch-grass range made very satisfactory gains. The straw was valued at one dollar a ton in the stack, and to this charge was added the cost of hauling and feeding in racks. While the straw-fed cattle made some growth, they did not put on any flesh during the winter feeding period. In summing up their winter feeding, it can be said that they came through with their hides on but that is about all. With the large gains made on grass during the grazing season, however, they finally reached a very satisfactory weight at a comparatively low cost. The straw in all cases was fed with some supplement. In two lots it was fed with two pounds of cottonseed cake with very satisfactory results. The final results when supplemented with silage, as noted above, were also good.

From these tests we can be reasonably sure that straw, when supplemented with either silage or cottonseed cake or both, will, in the case of an emergency, winter calves and yearlings very economically. Of course if either the straw or the cottonseed cake were much higher in price in proportion to other feeds, the costs would be different. It is possible that the proportion of cottonseed cake or silage used to supplement the straw might be changed to advantage, but that question will have to be answered by subsequent tests. The straw-fed cattle were slower to reach market weight and were not so smooth as those in the other lots; nevertheless they were very good cattle for the Western market.

The daily winter ration and daily gains of the various straw-fed lots are shown in Table V.

TABLE V. DAILY FEED AND DAILY GAINS OF CALVES AND YEARLINGS ON VARIOUS STRAW RATIONS

	Calves			Yearlings		
How fed	Daily ration		Daily gain	Daily ration		Daily gain
All the straw they would eat. 2 lbs. c. s. c.	Straw c. s. c.	17 2	.76	Straw c. s. c.	23 2	.39
Silage limited. All the straw they would eat.	Straw Silage	11 10	.16	Straw Silage	21 15	-.09
Silage and c. s. c. limited.	Straw	11		Straw	21	
All the straw they would eat	Silage c. s. c.	10 1	.78	Silage c. s. c.	15 1	.49

It will be noted that where straw is used the daily consumption of roughage will be slightly less than where good alfalfa is used, and that the addition of one or two pounds of cottonseed cake would not lower the consumption of either roughage. It should be borne in mind that the gains given above are the winter gains only and that all of these cattle made unusually good gains on grass during the grazing season.

INFLUENCE OF WINTER GAINS UPON GAINS MADE DURING GRAZING SEASON

The influence of the amount of gain made in winter upon the gain made the subsequent summer and fall is shown by Table VI and by the chart (Fig. 1). For convenience, the various lots, both calves and yearlings, have been grouped into five groups depending upon the amount of gain made while on winter rations.

These lots were wintered on different feeds as previously discussed and consequently made different gains, hence went onto grass the next spring in various degrees of condition. All the lots were together on grass for the spring, summer, and fall and any difference in gains made during the grazing season is presumably due to the difference in the gains made the preceding winter, or in other words, to the difference in their condition at the beginning of the grazing season.

TABLE VI. INFLUENCE OF WINTER GAINS UPON GAINS MADE DURING GRAZING SEASON

	Winter gains	Gains following summer and fall	Total for year
Average of the 4 lots making less than 50 lbs. winter gain	20	257	277
Average of the 7 lots making 50 to 99 lbs. winter gain	77	235	312
Average of the 6 lots making 100 to 149 lbs. winter gain	121	227	353
Average of the 4 lots making 150 to 199 lbs. winter gain	167	212	379
Average of the 5 lots making 200 lbs. or over winter gain	222	165	387

GRAPHIC CHART SHOWING THE INFLUENCE OF WINTER GAINS UPON GAINS MADE DURING GRAZING SEASON

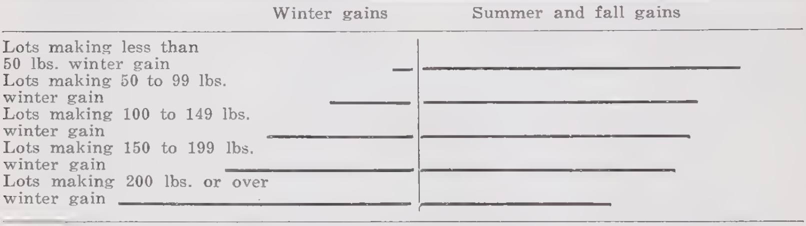

Fig. 1. The data of Table VI are shown graphically in the chart. The length of the line in the column for winter gain is proportional to the amount of gain made during the winter, while the length of the line in the column for summer and fall gain is proportional to the amount of gain made during the following summer and fall.

With very few exceptions the cattle which made the smallest gains during the winter feeding periods made the largest gains during the grazing season, while those making the largest winter gains made the smallest gains in summer. The cattle which made the large winter gains, however, made the largest total gains for the year. The cattle which came through the winter in the thinnest condition regained a part, but only a part, of their handicap during the following summer and fall. The proportion of the handicap regained varied in different instances. By averaging together all the heavier fed lots and comparing them with the lightest fed lots in each test, we find that the heavy fed lots were 97 pounds a head heavier than the three light fed lots at the end of the winter, but that at the end of the following summer they were only 44 pounds ahead. In other words, the light fed cattle, by making better gains in the summer recovered 55 percent of their loss as compared with the other lots during the winter feeding period.

It should be borne in mind in this connection that most of these cattle were wintered at least fairly well and the poorest of them, while losing some fat, made sufficient growth in most cases to hold their initial weight. The cattle receiving light winter rations made average yearly gains of 300 pounds and more and reached the age of 2½ years weighing around 1100 pounds, which compares very favorably with the average range steer. The results in this bulletin which seem to favor "light" feeding for wintering growing steers should rather be viewed as favoring medium feeding as compared with heavy or extra heavy feeding.

There is certainly a point in wintering cattle below which they lose vigor and vitality and become permanently stunted. This point is at present undetermined but we have under way tests which, when completed, will probably throw some light on this most interesting subject.

It should be explained that a calf can grow in frame and gain in weight and at the same time lose in fat. It was our judgment that most of the calves that gained less than one pound a day during the winter were not as fat at the end of the winter as they were at the beginning and it is certain that those calves which gained one-fourth to one-half pound a day lost a good deal of fat in spite of their gain in weight.

SUPPLEMENT

TEST NO. 4 PRELIMINARY REPORT

A fourth growing test was started January 6, 1921, with nine lots of ten calves each. These were possibly a little above the average in age, weight, and quality for the general run of range calves. The various lots were fed as shown below. These calves will be carried on to maturity but as this manuscript is written only the first winter, January 6 to May 6, 1921, has been completed; so the figures for this first winter are presented without any attempt at final conclusions.

Table VII. RESULTS OF FIRST WINTER'S FEEDING IN TEST NO. 4

Lot 1	Straw and one pound cottonseed cake
Lot 2	Straw and two pounds cottonseed cake
Lot 3	Alfalfa hay and corn silage
Lot 4	Alfalfa hay and peas and bald barley silage
Lot 5	Alfalfa hay and sunflower silage
Lot 6	Alfalfa hay (full feed)
Lot 7	Alfalfa hay (medium feed)
Lot 8	Alfalfa hay (light feed)
Lot 9	Alfalfa hay and sunflower silage (medium feed)

10 calves in each lot. Feeding period Jan. 6 to May 6 1921—120 days

	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9
Initial weight	548	548	542	548	548	548	548	548	548
Final weight	561	599	691	683	678	674	596	562	591
Gain per head	13	51	149	135	130	126	48	14	43
Daily gain	.11	.42	1.24	1.13	1.08	1.05	.4	.11	.36
Hay per day			15.33	13.84	14.25	20.90	13.71	11.51	10.73
Silage per day			17.2	16.81	17.12	17.16			9.73
Straw per day	16.35	13.36							
c. s. c. per day	1.00	1.96							

While the calves in all lots gained some weight only those that gained one pound or more a day held their own in condition. Those in Lot 3, getting alfalfa and corn silage, were possibly a little fatter than they were at the beginning of the test. Those in Lots 1 and 8 were quite thin. Those in Lot 1 looked poddy and rough, and appeared to be somewhat low in vitality, but we cannot be sure on this latter point until we know what they do on grass.

Station Bulletin 183 September, 1921

Oregon Agricultural College
Experiment Station

Eastern Oregon Branch Station

Shelter and Warm Water for Fattening Steers

By

E. L. POTTER

and

ROBERT WITHYCOMBE

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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SUMMARY

Fattening steers, fed and sheltered in the barn and having access to a lot for exercise, consumed the same amount of feed and made very little more gains than those fed in the open.

Fattening calves, given access to a shelter shed, consumed the same amount of feed and made the same gains as did those without the shed.

Fattening steers, given water warmed to an average of 43 degrees, consumed the same amount of feed and made the same gains as did those which received cold water.

FEED LOTS AT EASTERN OREGON BRANCH EXPERIMENT STATION

Shelter and Warm Water for Fattening Steers

Very few fattening cattle in Eastern Oregon are ever fed during the winter months in a bleak, open feed lot without some sort of a shelter. This shelter may consist of a modern barn, an open shed, a prepared windbreak, or a brush thicket. Probably the latter is the most commonly used and is possibly the most feasible and practical for most farm conditions. A good brush thicket where cattle can always find shelter from storms and a good bed ground is a valuable asset to any feed yard.

Another very important factor in cattle feeding is the water supply. Too often cattle are required to drink from muddy and inaccessible water holes, which freeze in winter, making it difficult for the cattle to drink at will. While all cattlemen will agree that feeding under such conditions cannot be expected to show profitable results, yet there is a wide-spread belief among most feeders that even if water is supplied in a modern way, still better results might be expected if it were warmed for the cattle by the use of a tank heater. There is also an opinion that better results would be obtained if cattle were given better shelter facilities than are usually provided on most farms. Realizing what a good brush thicket means in this regard they wish to know further what might be expected if cattle were fed in an enclosure such as a barn. It was in the hope of shedding some light on these points that the following experiments were planned at the Union station.

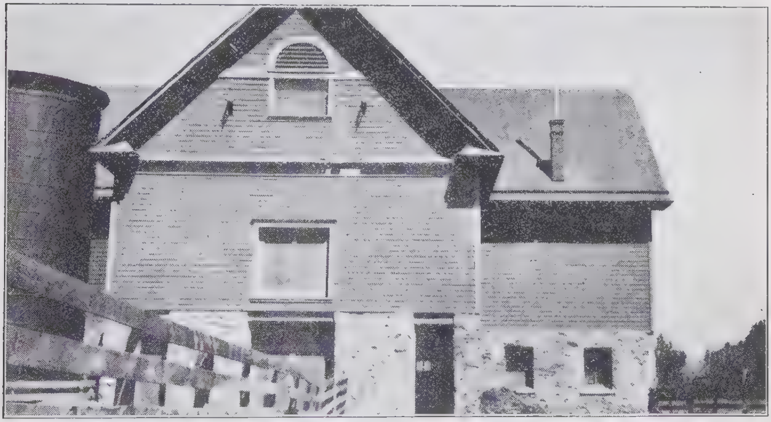

Fig. 1. Barn and yard in which Lot 1 was fed.

First, feeding two-year-old steers in a barn.

Second, feeding calves in a lot provided with an open shed.

Third, feeding two-year-old steers in a lot provided with warm water.

The experiment station at Union is located in the Blue Mountain region at an altitude of 2787 feet; hence the conditions under which these tests were conducted are quite typical of this particular region, and in fact represent in a fair degree the conditions under which a large percentage of the cattle are fed in the section of the State lying east of the Cascades.

The weather during the winter months is usually quite cold and windy, though the minimum temperature rarely ever is lower than 10 degrees below zero.

The ground usually remains frozen and the winds come mainly from the southeast during the major portion of the winter feeding period.

The total snow fall is about 30 inches and is pretty well distributed through the months of December, January, February, and March. In the Grande Ronde Valley where the experiment station is located the snow as a rule does not lie on the ground long, but blows about and accumulates in large drifts.

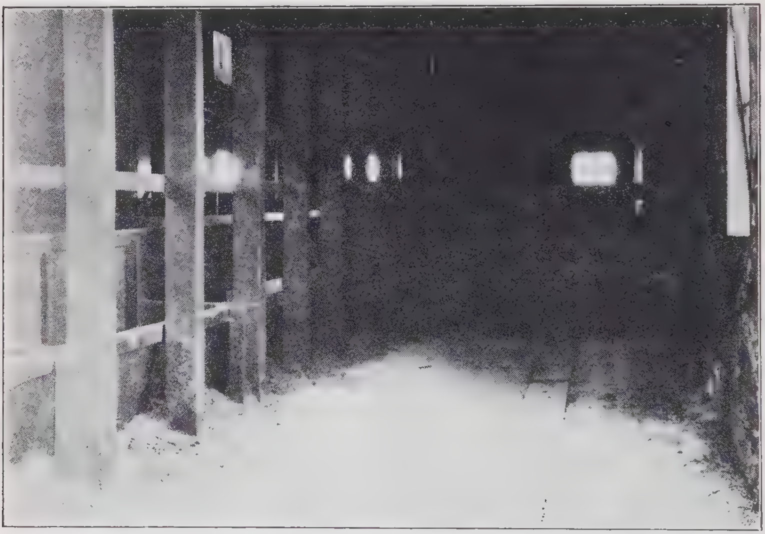

Fig. 2. Interior of barn in which Lot 1 was fed. Ten steers were quartered in this space 12x36.

The rainfall is comparatively light during these months. The five-year average for the total fall from December to April inclusive is 3.88 inches.

TABLE I. METEOROLOGICAL RECORD EXPERIMENT STATION, UNION, OREGON
Five-year Average for Winter Feeding Period 1916-1921 inclusive

	—Temperature—				—Precipitation —	
Month	Max.	Min.	Mean Max.	Mean Min.	Rain	Snow
December	54	5	37.03	24.74	1.16	4.58
January	53	–3	37.09	23.54	.76	7.50
February	52	11	39.58	24.56	.22	6.17
March	64	14	48.67	28.70	.49	8.4
April	73	19	57.43	31.44	1.25	2.9
Average for five-month period	59	9	43.96	26.60	.78	5.91

Feeder cattle as a rule do not make satisfactory gains when fed in the open during wet, muddy seasons, but seem to do best when weather conditions are dry and cold.

In this bulletin are given the results of three series of tests, which will be considered under the three divisions as stated above.

In each case the data given are averages of two year's work.

For shelter tests with lambs see Station Bulletin 175.

SHELTER FOR FATTENING STEERS

In the winter of 1919-20 and again in 1920-21 comparisons were made of shelter for fattening steers as compared with open-lot feeding. There were ten two-year-old steers in each lot. In the 1919-20 test the steers weighed 1200 pounds at the start and were fed for 82 days. In the 1920-21 test the steers weighed 948 pounds at the start and were fed for 120 days. Both lots were fed on alfalfa hay and silage. In the first test corn silage and peas-and-bald-barley silage and alfalfa hay were fed, while in the second test sunflower silage and alfalfa hay were used.

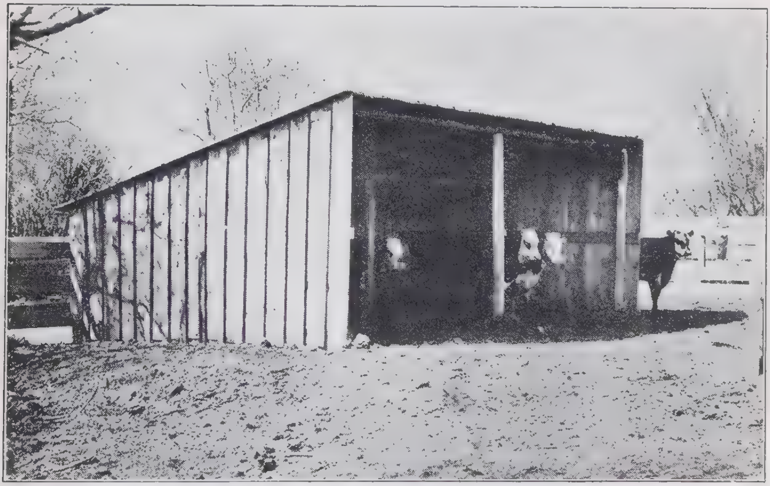

Fig. 3. Shed for wintering calves in Lot 2.

The steers in one lot were fed and sheltered in a space 12x36 in the barn and had access to an outside lot where they obtained water and exercise (see figures 1 and 2). Those in the second lot were fed in the open with no shelter other than a windbreak on the south and a tight board fence around the east end of the lot. A daily record was kept of the temperature of the barn and of the open lot. The average daily temperature in the barn was 42 degrees and in the open lot, 33 degrees, but of course the temperature of the open lot was more variable than that of the barn. The open lots were rather muddy a good share of the time, especially in the second test. The stream from which both lots obtained their drinking water was carried through the yards in a board flume and was thus kept free from ice and in condition so that the steers could drink easily at all times (see Fig. 4). The feed consumption and daily gains for the two tests are averaged and shown in Table II.

TABLE II. AVERAGE OF 1919-20 AND 1920-21 TESTS

	Lot 1 shelter	Lot 2 open lot
Hay per day	25.38	26.81
Silage per day	19.21	15.19
Daily gain	1.56	1.485

From the above it will be seen that the shelter increased the gains less than 1/10 pound daily. The lot under shelter ate more silage and a little less hay. At $8.00 a ton for hay and $5.00 a ton for silage the daily feed cost was 15 cents a day as compared with 14½ cents for the lot fed in the open. This difference in feed cost would offset the slight difference in gains. All of these differences, however, are so slight as to be within the limit of experimental error; hence it would seem on the basis of these two tests that the barn shelter made no material difference. With other types of shelter or under other conditions the results might have been different.

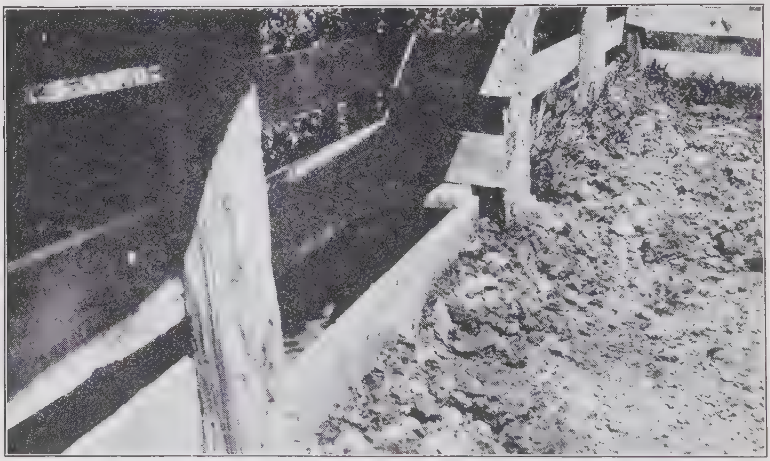

Fig. 4. Board flume from which all lots on cold water were watered. The flume is covered except where the steers drink.

In addition to the two tests given above, another lot in 1919-20 was fed and quartered in the barn without access to an outside lot. During the first few weeks of the test the cattle in this lot made very satisfactory gains, but toward the close of the experiment they appeared to grow stale; hence they did not make the final showing that the cattle did having an open lot for exercise or even those that were fed in the open.

SHELTER FOR CALVES

In the winter of 1917-18 two lots of six calves each were fed on alfalfa, peas-and-bald-barley silage, and barley. One lot was fed in the open without shelter, the second lot received feed in the open but had access to the small shed shown in Fig. 3. These calves weighed 543 pounds at the start and were kept on feed for 112 days. In the winter of 1918-19 the test was repeated with calves weighing 490 pounds at the start and fed for 82 days. The feed consumption and the gains made in the two tests are averaged and shown in Table III.

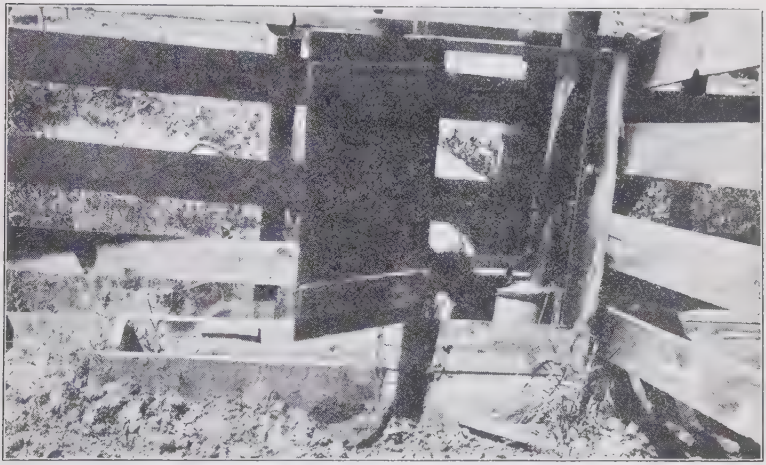

Fig. 5. Tank heater used to warm water for Lot 2. Note that the heater is enclosed to protect it from the stock but that a door in the enclosure permits access to it.

TABLE III. AVERAGE OF 1917-18 AND 1918-19 TESTS

	Lot 1 Fed in the open	Lot 2 Fed in the open with access to shed
Hay per day	12.39	11.64
Silage per day	10.26	10.26
Grain per day	5.08	5.08
Daily gain	1.90	1.87

The differences between the two particular lots both as to feed consumption and daily gain are negligible, and there was no real difference in the final condition of the calves in these two lots.

Of course it should be borne in mind that both these lots of calves were receiving really fattening rations and had they been on some of the lighter winter rations the results might have shown some advantage for the shelter. Moreover, the small open shed, shown in Fig. 3, did not afford the protection from storms that had been expected of it. At various times during the winter snow drifted into it badly in spite of the fact that the open side faced the opposite direction from the prevailing winds. There were times of course during the winter feeding period that the shed seemed to afford the calves some real comfort.

WARM WATER FOR FATTENING STEERS

In the winter of 1919-20 and again in 1920-21 comparisons were made between warm and cold water for fattening steers. There were ten two-year-old steers in each of two lots. In the first test the steers weighed 1200 pounds at the start and were fed for 82 days. In the second test the steers weighed 948 pounds at the start and were fed for 120 days. The cattle in both tests were fed on alfalfa hay and silage. In the first test the silage was corn and peas and bald barley, while in the second test it was sunflowers.

Both lots were fed in the open with no special shelter. Lot 1 obtained their drinking water from a running stream which was carried through the yard in a board flume. The flume was partly covered and the water flowed rapidly enough to prevent freezing. There were times during the feeding period when the yards became muddy, especially around the watering places; but aside from this the steers were always able to get all the water they wanted without difficulty. The flume which carried the water through the various yards is shown in Fig. 4.

The cattle in the second lot were fed in an adjoining yard and were watered from a trough in which the water was kept warm with a tank heater (see Fig. 5). A daily record was kept of the temperature of both warm and cold water. The average temperature of the warm water was 43 degrees and of the cold water 37 degrees Fahrenheit. The water in the trough was kept fairly uniform in temperature while the water in the flume was more or less variable ranging from 30 to 48 degrees. The feed consumed and daily gains for the two tests are averaged and shown in Table IV.

TABLE IV. AVERAGE OF 1919-20 AND 1920-21 TESTS

	Lot 1 cold water	Lot 2 warm water
Hay per day	26.81	27.21
Silage per day	15.19	15.18
Daily gain	1.485	1.48

From Table IV it would seem that warming the water had practically no effect upon either the feed consumption or daily gains. It is believed, however, that where the cattle are watered in troughs that give much trouble from freezing a tank heater would be a paying proposition, from the standpoint of convenience if for nothing else. It is also quite possible that in cases where the water supply is frozen a good share of the time during the winter feeding period, thus preventing the steers from getting all they want at times, warming the water might show some results. It is very evident, however, that in feeding cattle under similar conditions, such as are presented in these two tests, where they can get all the water they want at any time, it does not make any material difference whether the water is cold or warmed to an average of 43 degrees. In our tests, in fact, if there was any appreciable difference, the steers in the cold water lot made slightly the better showing of the two.

It is suggested, although not proved by actual tests, that the advantage often claimed for pumped, warmed, or artesian water, as compared with water from a creek or ditch, may lie in the fact that water in a trough is usually easy for the cattle to reach at any time, while creeks and ditches often have icy or muddy banks which the cattle will not go down until they become very thirsty.

Station Bulletin 184 September, 1921

Oregon Agricultural College

Experiment Station

Eastern Oregon Branch Station

Silage for Fattening Lambs

By
ROBERT WITHYCOMBE
and
E. L. POTTER

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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SUMMARY

Alfalfa hay and barley constitute a very satisfactory ration for fattening lambs.

Silage added to a ration of alfalfa hay and barley does not increase the gains materially, but may be used in connection with fattening lambs, provided it can be produced economically.

In terms of amounts of feed replaced per 100 pounds gain where alfalfa hay is valued at $8.00 and barley at $25.00 per ton, peas-and-bald-barley silage has a value of $5.05 and sunflower silage $3.96 per ton for fattening lambs.

Lambs fattened on alfalfa hay and barley, with and without silage, made very satisfactory gains and there was no apparent difference in the final condition of the finished lambs.

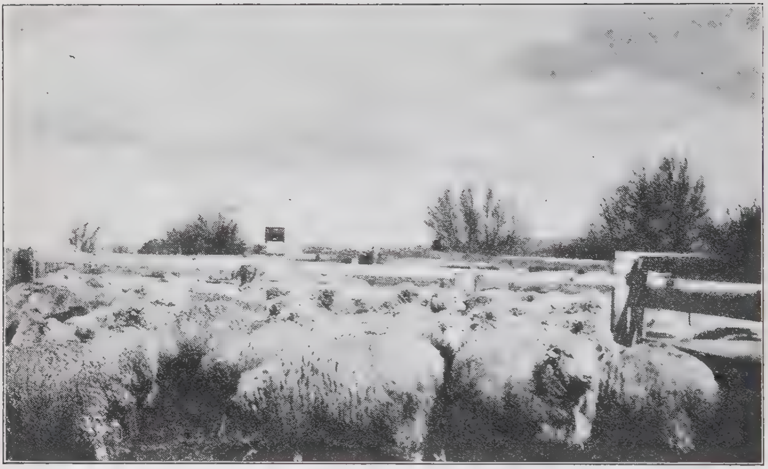

Fig. 1. Lambs after being fed 71 days on barley, alfalfa hay, and sunflower silage.

Silage for Fattening Lambs

PEAS-AND-BALD-BARLEY SILAGE

In the winter of 1918-19 a test was made to determine the value of peas-and-bald-barley silage for fattening lambs. One lot of 86 lambs was fed on one pound whole barley a day and all the alfalfa they would eat, while another lot of 86 lambs was given one pound of peas-and-bald-barley silage per day in addition to one pound of whole barley and all the alfalfa hay they would eat. The results are shown in Table I.

Fig. 2. Lambs that have had peas-and-bald-barley silage in addition to their ration of alfalfa hay and barley.

TABLE I. RESULTS OF FEEDING PEAS-AND-BALD-BARLEY SILAGE TO FATTENING LAMBS

	Lot 1 Alfalfa and barley	Lot 2 Alfalfa, silage and barley
Weight at beginning	92.3	91.98
Weight at close	111.7	112.8
Total gain	19.4	20.8
Daily gain	.29	.31
Alfalfa offered	2.40	2.17
Alfalfa refused	.34	.38
Alfalfa consumed	2.06	1.79
Barley	1.00	1.00
Silage	....	1.00

On the basis of the feed required to produce one hundred pounds of gain, one ton of the peas-and-bald-barley silage replaced 140 pounds of grain and 824 pounds of hay. On this basis the ton of silage would be worth $5.05.

It will be noted that the lot receiving silage made a daily gain of .31 pounds. While the silage lot made slightly the larger gain, yet the gains made by both lots were entirely satisfactory and the lambs put on a good finish. There was no noticeable difference in the finish of the two lots.

SUNFLOWER SILAGE

In the winter of 1920-21 a test was made to determine the value of sunflower silage for fattening lambs. One lot of 104 lambs was fed on a ration of one pound of whole barley and all the alfalfa they would eat, and a second lot was fed one pound sunflower silage in addition to the one pound of barley and all the hay they would eat. The results are shown in Table II.

Fig. 3. A choice lot of finished lambs.

TABLE II. RESULTS OF FEEDING SUNFLOWER SILAGE IN FATTENING LAMBS

	Lot 1 Alfalfa and barley	Lot 2 Alfalfa, silage and barley
Weight at beginning	75.6	75.6
Weight at close	93.7	94.5
Total gain	18.1	18.9
Daily gain	.25	.26
Alfalfa offered	2.62	2.37
Alfalfa refused	.33	.35
Alfalfa consumed	2.29	2.02
Barley	1.00	1.00
Silage	....	1.00

On the basis of feed required per hundred pounds gain, one ton of silage replaces 80 pounds of barley and 740 pounds of alfalfa. With hay valued at $8.00 and barley at $25.00 per ton sunflower silage in this case would have a value of $3.96 per ton. It will be noted that the daily gain without silage was .25 and with silage .26 pounds. These gains were very satisfactory in both cases and both lots took on a good finish. There was not enough difference in the gains to make any noticeable difference in the finish of the lambs.

DISCUSSION

These tests indicate that either sunflower silage or peas-and-barley silage make a good addition to barley and alfalfa for fattening lambs and that the advisability of using the silage depends entirely upon its cost as compared with alfalfa and barley. It has been demonstrated not only in these tests but in previous tests described in Station Bulletin 175, that in fattening sheep one pound of barley and all the alfalfa they will eat will produce good gains and a high finish. The addition of silage, therefore, is a matter of economy rather than of additional gains or finish. Where silage can be easily and cheaply grown it will cheapen the ration, but if conditions are unfavorable to growing silage its use will make the ration more expensive.

Fig. 4. A car of Experiment Station lambs at the Portland Stock Yards.

We have made no comparisons between peas-and-barley silage and corn silage for lambs, but our tests with cattle indicate that peas-and-barley silage compares very favorably with good corn silage. We consider corn silage the standard silage wherever it can be grown. In sections where this crop cannot be grown successfully, however, peas-and-barley, sunflowers, or sweet clover can usually be grown to good advantage.

It is interesting to note, by way of comparison, that in seven trials with corn silage in the corn belt as compiled by Henry and Morrison the silage did not materially increase the gains made, but that one ton of silage replaced 160 pounds of grain and 800 pounds of hay. Valuing the hay at $8.00 and the grain at $25.00 the silage would have a value of $5.52 a ton. While these tests were conducted under conditions quite different from those at the Union station, the results in general check quite closely. It is probable that the silage made from well-matured corn was somewhat better than that fed at the Union experiment station and the hay not as good, which would tend to give the corn belt silage the higher value.

Station Bulletin 185 November, 1921

Oregon Agricultural College
Experiment Station

Preliminary Report on

The Management of Willamette Valley Soils

Department of Soils
Department of Agricultural Chemistry

CORVALLIS, OREGON

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*On leave of absence.

The Management of Willamette Valley Soils

A PRELIMINARY REPORT

By

DEPARTMENT OF SOILS

and

DEPARTMENT OF AGRICULTURAL CHEMISTRY

Organization. The work herein reported is an important part of the Oregon Soil and Soil Water Investigations conducted by the Soils department, partly in cooperation with the department of Agricultural Chemistry of the Oregon Agricultural College Experiment Station, and partly in cooperation with the United States Bureau of Soils. This progress report is published to meet the demands for facts bearing on the reclamation and improvement of the Willamette Valley soils. The information presented in this bulletin is based on the facts which have been thus far established by the investigations under way, provided for by Chapter 350, General Laws of Oregon, 1919, and the continuation of the law in 1921.

Improvement and Maintenance of Soils. The cooperative soil surveys of the Willamette Valley and chemical invoice of important fertility elements in each type mapped are laying the foundation for developing formulas for permanent agriculture for these lands. The soil survey field data are shown on the topographic maps of the United States Geological Survey or prepared base maps using a scale of one inch to the mile, showing all roads, buildings, streams and other important land marks, the extent of each distinct soil type being represented in a different color. Such maps enable representative official samples to be collected for analysis and are desired in the location of field fertilizer trials. When the work is completed, the farmer or prospective settler may know what type or types of soil occur on a given farm, what their average chemical and physical composition is, what crops and types of farming are best suited to these soils, and what treatments are needed to develop and maintain their productiveness.

Progress of the Work. About fifty percent of the Willamette Valley has been soil surveyed. With the completion of field work in Polk county, there will have been mapped 2,596,705 acres; and there still remain to be mapped in Linn, Lane, and Marion counties, exclusive of forest reserve, 2,294,176 acres. Field work has been completed in the other five Valley counties, and the report and soil map of Yamhill county has been published.

Chemical analyses have been made of each soil type in Yamhill, Washington, and Multnomah counties, including 101 samples and 929 determinations. These are made available, for the first time, in this preliminary report.

A dozen field experiments are in progress to study the reclamation and fertility problems involved in the management of the chief soils of the Valley, while minor types are tested by pot fertilizer tests in the greenhouse as facilities permit. In this bulletin are given the important results thus far obtained.

As a matter of state policy it is important that permanent systems of soil management be definitely established before the virgin fertility of our soils is depleted to the point of uncertain profit. It is hoped, therefore, that this work may be speeded up so that the field survey and chemical invoice of Willamette Valley soils may be completed, and the field fertilizer trials extended, in order that a comprehensive report with general soil maps may be prepared in time for distribution by the opening of the proposed World's Fair in 1925.

Classification of Willamette Valley Soils. The country rock and the geological development of the unconsolidated soil material are important considerations in soil classification. The soils of the Valley are divided into three groups; namely, (1) the residual soils of the upland, or red hills from primary and secondary basaltic material, (2) the old valley filling soils, alluvial floor of the valley of mixed material, and (3) recent river and stream bottoms of mixed alluvial material. These groups are divided into soil series having similar geological origin, topography, color, lime content, natural drainage, structure and subsoil conditions; e. g., Dayton series, called white land, and first mapped on Dayton Prairie. Each series may contain a number of types which are similar in respect to the foregoing qualifications, and differ only in texture; e. g., Aiken silt loam, Aiken clay loam, etc. The following key shows the soil series thus far established in the Willamette Valley, with their distinguishing characteristics and their relation to the country rock.

TABLE I. KEY TO CLASSIFICATION OF WILLAMETTE VALLEY SOILS.

I. RESIDUAL SOILS—(Red Hill)	
(a) From Basaltic Rock	
Olympic	Brown surface soils on brown subsoils
Aiken	Red surface soils on red subsoil
Cascade	Brown surface soils on yellow subsoils
Viola	Gray-brown soils on yellow-brown subsurface on mottled compact subsoils—poor drainage
(b) Sedimentary shales and sandstone	
Melbourne	Brown soil on yellow subsoil
Sites	Red soils on red subsoil
Carlton	Grey-brown soil on grey mottled subsoil—imperfect drainage
II. OLD VALLEY FILLING SOILS—Mixed material	
Willamette	Brown soil on light brown subsoil
Hillsboro	Brown soil on sandier brown subsoil
Dayton (white land)	Grey soil on mottled stiff grey and yellow subsoil—poor drainage
Amity (half white land)	Grey-brown soil on mottled grey and yellow subsoil—poor drainage
Concord	Grey Dayton surface on Amity subsoil—poor drainage
Salem	Brown soil on light brown gravelly subsoil
Grande Ronde	Light yellow-brown soil on yellow mottled subsoil
Holcomb	Grey-brown soil on grey compact subsoil—poor drainage
Clackamas	Dark brown soil on gravelly brown compact subsoil
Canby	Dark brown soil on brown loose gravelly subsoil
III. RECENT SOILS—Mixed alluvial material	
Newberg	Brown soils on brown sandier subsoil (1st bottoms mainly)
Chehalis	Brown soils on brown heavier subsoils (2d bottoms mainly)
Wapato	Brown soils on grey-brown subsoil—poorly drained
Whiteson	Grey soil on drab plastic mottled subsoil—drainage poor
Cove (black sticky)	Black soil on dark subsoil—poor drainage
Gales	Brown soil on light brown gravelly subsoil
Molalla	Dark brown soil on mottled subsoil—poorly drained
Peat and Muck	(Beaver dam) Soils high in organic material
IV. MISCELLANEOUS SOILS—	
Rough—Stony	
River wash	

Reclamation. The soil survey determines the extent of each wet soil type, and together with preliminary drainage surveys in cooperation with the United States Office of Irrigation and Drainage Investigations, the wet areas in the Valley are being outlined and preliminary outlet systems to the main wet areas are being designed. The wet soil types in the valley floor and low foot slopes of adjacent hills constitute about one-third of the total area of the valley floor, or about 750,000 acres. These types are confined chiefly to the soils of half a dozen series. The soils of Dayton (or white land) series are estimated at 100,000 acres; the Amity (or half-white land) series at 200,000 acres. These are the main wet soils in the old valley filling group. In the recent stream bottom group, the Wapato, Cove, and Peat series, and in the hill group, the Carlton, and Viola series have imperfect drainage.

Preliminary drainage surveys show that the reclamation of most of these lands is feasible and desirable and that they will pay a better rate of interest on the total investment when drained. Scientific methods of tile drainage for these lands have been established. The results of experiments that have developed fairly definitely the best depth, distance apart, and capacity for tile drains and the procedure in drainage district work, are as reported in Oregon Agricultural College Experiment Station Bulletin 178.[1] Drainage will double the productiveness of one-third of the land in the valley floor, and is the first step in the improvement of these wet soils.

Proper supplemental irrigation has been proved profitable on the mellow soils of river and stream bottoms, and on the well-drained mellow soils of the valley floor, when applied to late season crops and intensive crops where the water can be secured at reasonable cost. Irrigation experiments extending over fourteen years show that it is possible to make fifty to sixty percent increase on the naturally drained brown soils with proper irrigation, and seventy-five to one hundred percent increase on the sandy loams of the river bottom. Detailed results of these experiments may be found in Oregon Agricultural College Experiment Station Bulletins 122[2] and 161.[3]

TABLE II. FERTILITY IN LOWER WILLAMETTE VALLEY SOILS

[Analysis by Department of Agricultural Chemistry, Oregon Agricultural College Experiment Station]

Soil type	Depth analyzed	County	Pounds fertility per 2,000,000 of soil				
			Nitrogen	Phosphorus	Potassium	Sulfur	Calcium
I. Residual (Red Hill Soils):							
(a) Igneous Division—							
Olympic Silt Loam	0″—15″	Washington	2,480	1,920	34,200	....	28,000
Aiken Silt Loam	0″—20″	Yamhill	3,340	3,400	12,600	340	5,200
Aiken Silt Loam	0″—12″	Washington	2,060	640	32,200	70	11,400
Cascade Silt Loam	0″—12″	Multnomah	2,800	2,540	31,200	320	21,200
Olympic Clay	0″—10″	Yamhill	3,020	500	16,600	....	22,200
Aiken Silty Clay Loam	0″—10″	Yamhill	5,400	4,200	21,000	540	13,200
Aiken Clay Loam	0″—15″	Washington	2,300	4,780	9,400	....	8,400
Cascade Loam	0″—12″	Multnomah	1,400	1,400	34,800	....	16,400

TABLE II. FERTILITY IN LOWER WILLAMETTE VALLEY SOILS—Continued

[Analysis by Department of Agricultural Chemistry, Oregon Agricultural College Experiment Station]

Soil type	Depth analyzed	County	Pounds fertility per 2,000,000 of soil				
			Nitrogen	Phosphorus	Potassium	Sulfur	Calcium
(b) Sedimentary Division—							
Melbourne Loam	0″—10″	Yamhill	2,140	2,380	27,400	....	....
Melbourne Loam	0″—12″	Multnomah	4,800	3,060	31,600	....	34,000
Melbourne Clay Loam	0″—18″	Washington	1,020	1,400	34,600	162	11,400
Sites Silty Clay Loam	0″—20″	Yamhill	3,800	1,420	12,000	....	6,000
Carleton Clay Loam	0″—10″	Yamhill	5,000	1,940	20,800	....	18,800
Carleton Clay Loam	0″—20″	Washington	3,000	1,660	39,800	....	19,000
Melbourne Silt Loam	0″—15″	Washington	1,380	1,060	35,800	....	25,800
Sites Silt Loam	0″—12″	Yamhill	4,800	140	15,800	....	6,200
Carleton Silt Loam	0″—16″	Washington	1,180	1,260	39,400	124	23,600
II. Old Valley Filling:							
(a) Basaltic and Sedimentary—							
Willamette Silt Loam	0″—12″	Yamhill	3,000	2,240	42,800	390	12,400
Willamette Silt Loam	0″—18″	Washington	1,660	3,440	37,000	260	22,400
Hillsboro Silt Loam	0″—30″	Washington	2,340	1,320	33,400	260	13,600
Amity Silt Loam	0″—18″	Washington	2,740	2,780	37,800	360	16,800
Dayton Silt Loam	0″—10″	Yamhill	2,200	560	39,200	....	13,400
Dayton Silt Loam	0″—16″	Washington	4,200	2,160	31,600	....	25,800
Salem Loam	0″—12″	Multnomah	3,200	2,700	32,200	640	27,000
Salem Gravelly Loam	0″—12″	Multnomah	2,600	2,880	29,200	....	27,600
Hillsboro Loam	0″—12″	Multnomah	5,000	6,120	35,400	....	24,800
Hillsboro Sand Loam	0″—12″	Multnomah	2,600	4,360	32,600	....	31,000
Fairview Loam	0″—12″	Multnomah	1,400	2,700	33,600	....	24,600
(b) Sedimentary—							
Grande Ronde Silty Clay Loam	0″—20″	Yamhill	6,800	2,440	24,200	700	5,000
III. Recent Alluvial Soils:							
(a) Basaltic and Sedimentary—							
Newberg Silt Loam	0″—18″	Yamhill	2,900	1,580	18,400	....	53,600
Newberg Silt Loam	0″—12″	Multnomah	800	1,840	21,400	....	71,400
Wapato Silt Loam	0″—12″	Yamhill	5,800	1,620	35,000	460	13,400
Wapato Silt Loam	0″—14″	Washington	3,140	600	29,400	380	25,000
Wapato Silt Loam	0″—24″	Multnomah	6,000	3,840	25,000	....	17,000
Wapato Silty Clay Loam	0″—16″	Washington	2,660	1,300	40,000	....	16,800
Wapato Silty Clay Loam	0″—10″	Multnomah	6,200	2,800	29,400	....	31,200
Cove Clay	0″—12″	Yamhill	5,000	1,200	25,200	....	25,600
Whiteson Silt Loam	0″—12″	Yamhill	3,200	1,000	43,200	320	21,600
Whiteson Silt Loam	0″—18″	Washington	9,400	920	12,200	1,100	16,600
Newberg Clay Loam	0″—12″	Multnomah	5,400	1,580	26,600	680	35,800
Wapato Loam	0″—24″	Multnomah	2,600	1,140	27,800	....	51,000
Wapato Sandy Loam	0″—12″	Multnomah	2,400	2,100	25,000	....	52,000
Chehalis Silt Loam	0″—18″	Washington	4,000	1,520	25,800	....	18,800
Chehalis Fine Sandy Loam	0″—20″	Yamhill	940	980	22,200	162	58,200
Chehalis Silty Clay Loam	0″—14″	Washington	3,100	1,240	21,800	140	30,200
Chehalis Loam	0″—12″	Washington	3,980	1,040	14,000	....	51,600
(b) From Mixed Rocks—							
Sauvie Sandy Loam	0″—12″	Multnomah	6,600	2,440	29,200	940	27,400
Sauvie Silty Clay Loam	0″—10″	Multnomah	5,000	2,000	24,000	....	24,400
Columbia Fine Sand	0″—36″	Multnomah	1,200	1,740	32,600	....	52,400
(c) From Basaltic Rock—							
Gale Loam	0″—18″	Washington	5,740	3,700	19,000	....	28,600
Gale Gravelly Loam	0″—12″	Multnomah	2,400	2,180	28,200	....	65,400
IV. Peat:							
Peat	0″—12″	Yamhill	24,600	1,880	11,800	3,920	11,800
Peat	0″—12″	Washington	38,200	2,060	10,200	5,000	48,200

Chemical analysis of major soil types has kept fairly close pace with the field work. Analyses are made for the purpose of securing an inventory of plant food elements in the various soil types and to secure data upon which to base procedure in fertilizer experiments. The analytical data for the surface soils of Multnomah, Washington, and Yamhill counties are expressed in Table II as pounds of nitrogen, phosphorus, potassium, and sulfur contained in 2,000,000 pounds—approximately six and one-half inches depth over an acre, or the depth one would ordinarily turn with the plow. The combined use of Tables II and III enables one to arrive at some very definite conclusions relative to the native or potential fertility of certain soil types.

In the growing of crops like alfalfa, clover, and corn, all of which demand relatively large amounts of phosphorus, the advantage possessed by such types as Melbourne Loam, Willamette Silt Loam, Hillsboro Loam, and Gale Loam over Olympic Clay, Sites Silt Loam and Dayton Silt Loam is at once apparent. So also is the advantage possessed by such types as Olympic Silt Loam, Melbourne Silt Loam, and Willamette Silt Loam over Sites Silt Loam, Newberg Silt Loam, and Chehalis Loam in the element potassium. Generally speaking, soil types low in phosphorus and potassium may safely be assumed to stand in need of immediate application of phosphorus and potash-carrying fertilizers, and fertilizer trials for various crops may well be planned to determine the practicability of phosphorus fertilization on any type that has less than 1,600 pounds of phosphorus in 2,000,000.

Only the highly organic soils are rich in sulfur. The extremely small amounts of this element in many other types suggests at least the desirability of determining by direct trial the response to be expected from the various crops from the application of sulfur-carrying fertilizers.

With comparatively few exceptions the surface soils are well stocked with the element nitrogen, combined of course in the form of organic matter. In this connection, however, it should be borne in mind, especially by the farmers of these lands, that the heavy rainfall that is characteristic of the Willamette Valley generally operates to slow up very materially the activities of the soil's bacterial life that converts unavailable organic nitrogen to the available inorganic forms. The heavy drainage, too, very effectively leaches from these soils the soluble form of nitrogen during a part of the year when crops stand in need of that element of plant food. Slow conversion of organic nitrogen to available forms, combined with excessive leaching, brings about a set of conditions that demand for maximum production, even for those types that are relatively well supplied in nitrogen, the application of readily available nitrogen carriers. Nitrogen in sufficient amounts to supplement the rather large amounts already present in these soils may ordinarily be expected from reasonable applications of barnyard manure.

Table III. FERTILITY REMOVED IN CROPS

	Nitrogen	Phosphorus	Potassium	Sulfur
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*
Alfalfa, 4 tons	200	18	96	28
Clover, 4 tons	160	20	120	13
Field pea hay, 4 tons	...	...	...	7
Wheat, 50 bushels	71	12	13	5
Wheat straw, 2½ tons	25	4	45	6
Oats, 50 bushels	33	6	8	6
Oat straw, 2½ tons	31	5	52	9
Barley, 50 bushels	42	8	10	3
Barley straw, 1¼ tons	16	3	24	3
Potatoes, 200 bushels	42	8	60	3
Corn, 15 tons fodder	90	30	120	5
Rutabagas, 20 tons	76	48	160	...
Sugar beets, 10 tons	50	18	157	2
Cabbages, 10 tons	60	8	66	39
Fat cattle, 100 lbs	25	7	1	...
Milk, 10,000 lbs	57	7	12	...
Butter, 400 lbs	0.8	0.2	0.1	...
3-year rotation:				
Wheat, 50 bushels+	96	16	58	11
2½ tons straw	...	...	...	...
Clover, 4 tons+	...	20	120	13
Potatoes, 200 bushels	42	8	60	3
	+	44	238	27

Table IV. FERTILITY IN FARM MANURE AND FERTILIZERS

Material	Pounds per ton			
	Nitrogen	Phosphorus	Potassium	Sulfur
Fresh farm manure	10	3	8	5
Barnyard manure	10	3	8	5
Sodium nitrate	310	...	...	...
Ammonium sulfate	400	...	...	500
Raw rock phosphate	...	250	...	...
Acid phosphate	...	125	...	144
Potassium sulfate	...	...	850	324
Potassium chloride	...	...	850	...
Wood ashes	...	10	100	...
"Complete" fertilizer (average)	33	88	33	...
Gypsum	...	...	...	360
Crude sulfur (98%)	...	...	...	1,960

Fertility Removed by Crops. Table III shows that the legumes, corn, and root crops are heavy feeders of both phosphorus and potassium. Potassium is used in especially large amounts by the root crops. Sulfur is drawn upon heavily by the legumes and the cabbage family.

Fertility Returned in Fertilizers (Table IV.) Phosphorus is one of the necessary plant-food elements for the growth of all crops, and is regarded as the master key to permanent agriculture in humid sections. Crops use relatively large amounts of phosphorus compared with the amount in the soil. Two-thirds of the phosphorus taken by the crop goes to the seed, and is therefore lost from the farm when the grain is sold. The only way this loss can be made up in general farming is by the purchase of phosphate fertilizer. On the other hand, all of our heavier soils are well supplied with potassium, and in the crop this element remains, for the most part, in the straw and stalks, which can be returned to the soil. Nitrogen, while often a limiting element, can be supplied from the air by means of a legume crop, which can be turned under. Gypsum, superphosphate, and manure are best used to supplement the supply of sulfur in these soils.

There are three carriers of phosphate available for agricultural use in the Willamette Valley; viz., acid phosphate, steamed bone meal, and ground raw rock phosphate. The former contains phosphorus in an available form, besides about seven pounds per hundred of sulfur; it should be used for immediate results. Rock phosphate and bone meal are best used in large amounts in combination with organic matter. Potassium can be purchased as either the sulfate of potash or the muriate of potash.

Results of Field Experiments. Fairly complete and permanent fertilizer experiments are now in progress on the main soil types of the Willamette Valley. Several of these are located on the home Station farm and include crop rotation, so that more than one crop is represented each year. Certain applications have proved regularly profitable, and their use is being demonstrated by cooperative trials with the county agricultural agents. The several trials and their location are shown in Table V.

TABLE V.—SOIL RECLAMATION AND FERTILITY EXPERIMENTS

No.	Location	Soil type	When started	Number and kind of plots	Treatments giving increases
1	College Station Farm...	Dayton Silty Clay Loam.	1914	Drainage, 9.....	Manure; lime; gypsum.
2	College Station Farm...	Willamette Silty Clay Loam.	1909	Irrigation, 44...	Irrigation; rotation.
3	College Station Farm...	Willamette Silty Clay Loam.	1914	Fertility, 25....	Manure; lime; phosphate; sulfur.
4	College Station Farm...	Willamette Silty Clay Loam.	1914	Rotation, 86....	Clover sod land.
5	West Stayton (discontinued).	Salem Gravelly Loam..	1911	Irrigation, Fertility, 22.	Irrigation; manure; phosphate; lime.
6	College Station Farm...	Dayton Silty Clay Loam.	1919	Fertility, 24....	Manure; water; phosphate; lime.
7	College Station Farm...	Amity Silty Clay Loam.	1915	Rotation and manure, 14.	Irrigation; rotation; manure.
8	College Station Farm...	Cove Clay............	1915	Soil Improvement, 13.	Manure; quicklime.
9	1 mile east of Corvallis..	Newberg Sandy Loam.	1914	Fertility, 50....	Manure; phosphate; nitrogen.
10	A. Abraham's, 6 miles northeast of Corvallis.	Carlton Clay Loam.....	1921	Fertility, 22....	Sulfur; phosphate.
11	A. G. Salzman's, 1 mile south of Crown Point.	Cascade Silt Loam.....	1920	Fertility, 20....	Phosphate; manure; sulfur.
12	College Station Farm...	Willamette Silty Clay Loam.	1920	Manure and straw, 16.	

Recommendations. Drainage is the first step in the improvement of one-third of the land in the valley floor. About one-half of this land can be tiled without crossing the land of other owners. The larger areas will require district outlet ditches. Drainage of nearly all these lands is feasible now.

Proper supplemental irrigation will pay on the naturally drained free working soils of the stream bottoms, where water is readily available and applied to late season and intensive crops.

Rotation of crops costs little and is very profitable on all the soils of the Valley; it permits increasing the humus and nitrogen supply by the turning under of clover sod and other crop residues. As a seven-year average, rotation on the Oregon Agricultural College Experiment Station farm has given an average net profit of $8.82 with rainfall farming and $14.09 with irrigation farming above the profit from continuous cropping.

TABLE VI. VALUE OF ROTATION—7-YEAR AVERAGE

[Oregon Agricultural College Experiment Station, Department of Soils]

Treatment	Average yearly yield		Average net profit			Water requirement (lbs. per lb. dry matter)
	Acre	Acre inch	Acre	Gain from rotation or manure	Acre inch	
BEANS:						
Continuous	9.24	....	11.55	....	....	2,909
Rotated	10.13	....	20.37	8.82	....	2,249
Rotated and manured	12.91	....	21.26	9.71	....	1,900
Irrigated continuous	9.85	3.82	15.37	....	5.12	2,622
Irrigated and rotated	15.74	6.10	29.46	14.09	9.82	1,794
Irrigated, rotated and manured	18.29	7.14	38.39	23.02	12.80	1,425

The general use of farm manure pays very well on the Valley soils. As a seven-year average from one to five dollars an acre has been realized from light applications once in three years.

Gypsum can be profitably used as a top dressing on clover and alfalfa.

Profits from liming are more certain on the red hill soils and worn grain lands in the more humid sections, and on the heavy tiled soils previous to seeding down clover.

Phosphate fertilizers give good returns on the hill soils and the Valley soils that have been cropped heavily to grain crops.

Except on deep peat soils potassium is not likely to prove profitable.

TABLE VII. SOIL MANAGEMENT CHART FOR WILLAMETTE VALLEY

Soil type	Fertilizer needed	Crops to which applied	Method	Rate
1. Red Hill soils	Superphosphate	Clover—Potatoes, grain, corn.	Once in 3-year rotation ahead of cash crop. Broadcast on land or with fertilizer attachment on planter.	200-300 lbs.
	Lime to start clover.	On old grain land for clover.	Broadcast before seeding down.	2-3 tons.
	Land plaster	Legumes	Broadcast	100 lbs.
	Nitrogen	Potatoes, corn and grain when following non-legume.	Broadcast	100-200 lbs.
2. Valley soils—well drained.	Superphosphate	Grain—potatoes	Same as above	
	Nitrogen	Potatoes when following non-legumes.	Broadcast	100-200 lbs.
Wet Heavy (white and half-white).	Lime—after drainage.	Before clover	Broadcast before seeding down.	2-3 tons.
3. Recent stream bottom soils—Cove (black sticky) Wapato.	Drainage first	Alsike, beans, hairy vetch.		
Newberg sandy (1st bottom).	Phosphate with nitrogen added on non-legumes.	Alfalfa and clover, potatoes, corn, grain, beans.		As above.
	Land plaster	Legumes		
Chehalis — brown soil (2nd bottom).	Plaster on legumes	Wheat, barley		
Peat	Potash on deep peat Superphosphate on acid peat.	Onions, celery, oats, carrots.		

All Valley soils need humus. Rotation—very profitable. Manure—very profitable. Gypsum is excellent for getting clover and young alfalfa—uncertain on vetch.

EXPERIMENT STATION BULLETINS REFERRED TO OR BEARING ON IMPROVEMENT OF WILLAMETTE VALLEY SOILS

[1]Powers, W. L., Cretcher, Ward. Farm Drainage. Ore. Exp. Sta. Bul. 178. 1921.

[2]Powers, W. L. Irrigation and Soil Moisture Investigations in Eastern Oregon. Ore. Exp. Sta. Bul. 122. 1914.

[3]Powers, W. L. Duty of Water in Irrigation. Ore. Exp. Sta. Bul. 161. 1920.

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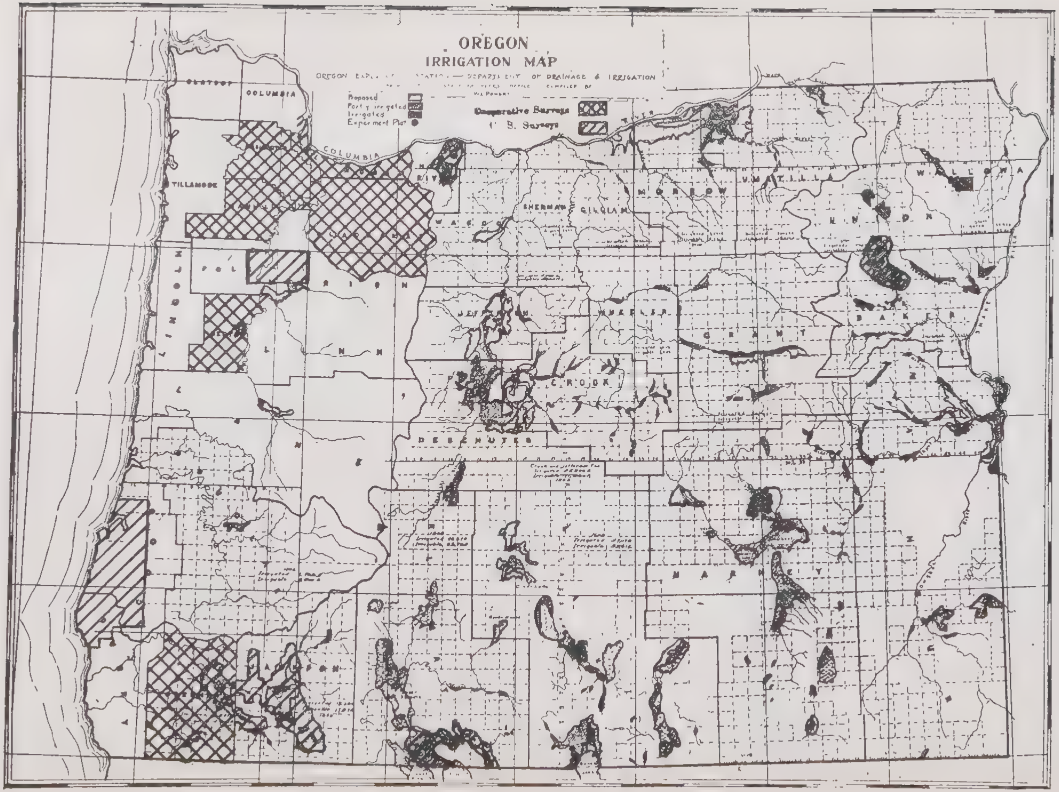

MAP SHOWING PROGRESS OF SOIL SURVEYS.

Detailed soil surveys have been made of cross-hatched areas, constituting only one-fifth of the tillable area of the State. General or feasibility surveys have covered most of the shaded areas, thus increasing the total area covered to one-third of the tillable area of the State. At the present rate two or three summers will be required to complete the soil survey of the Willamette Valley. This should be completed before the 1925 fair.

Station Bulletin 186 November, 1921

Oregon Agricultural College
Experiment Station

Department of Horticulture

A New Test for Maturity of the Pear

Pear Harvesting and Storage Investigations

(Third Report)

By

A. E. MURNEEK

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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SUMMARY

Pear Harvesting and Storage Investigations have been conducted by this Station since 1917 in both the Rogue River and Willamette valleys. The present, third, report on this work contains data and results of the past four seasons, covering but one phase of the subject, the study and development of a reliable test for maturity of the pear.

The "pressure" test has been found to be a most accurate and practical means of measuring the stage of ripeness of pears, particularly Bartletts. In this respect it appears to be more delicate and convenient than any other test heretofore known or applied for this purpose. It is based on a definite correlation between the degree of maturity of the fruit and resistance to pressure of tissues of the cortex and epidermal regions.

A special apparatus, known as the "pressure tester," has been constructed for this purpose. Several thousand tests were taken by means of this instrument. It is now in use in a number of pear-growing districts in Oregon and Washington. It promises to be of the widest practical application for determining the time of picking of almost all varieties of pears and possibly apples also.

Extensive experience with Bartletts has shown that harvesting of this variety should commence when the pressure test indicates an average resistance of 35 pounds. The lower limit at which it is still safe to pick Bartletts is 25 pounds. Much more mature fruit, however, may be safely shipped fresh to nearby markets only, or still better to the cannery or the drying plant.

The Bosc during its picking season should register 24 to 20 pounds, as measured by this method of testing. Other late fall or winter pears show somewhat different but just as consistent figures. Tables of seasonal tests with practically all leading commercial varieties of pears are given.

Only freshly picked uninjured fruit can be employed for testing by this method. To overcome individual variations each lot must be made up of 10 to 15 specimens. They should represent an average condition of the orchard or a particular section thereof.

Investigations of increase in size of Bartletts show a close correlation between increase in transverse diameter and a corresponding increase in weight. Average seven-day increments in this respect were found to be 5.1 percent in size and 17.7 percent in weight, while such average increase in a fourteen-day period was 10.1 percent and 35.4 percent, respectively. The ratio of percentage increase in diameter to percentage increase in weight is close to 1 : 3.5. In order safely to realize the largest possible tonnage, however, the exact stage of maturity of the fruit must be determined. The pressure test may be used as the most reliable guide for this purpose.

A New Test for Maturity of the Pear

Pear Harvesting and Storage Investigations

(Third Report)

INTRODUCTION

Protracted experience has taught the grower that pears, unlike most other fruits, must be harvested in a comparatively immature condition. Thus Bartletts, our predominating commercial variety, for instance, when picked quite hard and green will ripen off the tree and attain the highest quality. In most sections, however, the harvesting season of this variety usually extends for a period of twenty-five to thirty-five days, while it may take six to eight weeks from the date of the first commercial picking to the time the fruit becomes fully ripe on the tree[1]. Hence there are often considerable variations in the picking dates, which are entirely independent of the usual seasonal oscillations of the harvesting period. The question naturally arises as to when is a pear, Bartlett for example, ready to be picked, in order that the highest keeping and eating quality may be realized. But this leads us directly to the prerequisite consideration of the changes in maturity of the fruit.

Many tests have been used to ascertain the degree of development or stage of maturity of pears, such as changes in the color of the skin or epidermis; ease with which the fruit stem will separate from the spur; plumpness and smoothness of the fruit as a whole; the color and toughness of seeds; ease with which the finger may be pressed into the fruit; testing for sweetness by means of chewing, or for disappearance of starch by means of potassium iodide; and others too numerous to mention here. Ordinarily, however, the picking season for fresh shipments of Bartletts commences when the fruit approaches 2¼ inches in its largest transverse diameter. Thus it is seen that there exists a great diversity of opinions regarding the means of determining the exact stage of maturity of pears. The situation becomes still more aggravated due to the uncertainty and frequent fluctuations of the market.

Mindful of this situation, the Oregon Agricultural Experiment Station has during the past few seasons endeavored to find a simple but reliable test or indicator for maturity of the pear. This has been made an integral part of the Pear Harvesting and Storage Investigations, which were begun in the Rogue River Valley in the summer of 1917 and were extended to and continued in the Willamette Valley. A brief account will be given here of that part of the preliminary work touching directly upon the subject of maturity.

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[1] J. R. Magness. Investigations in the ripening and storage of Bartlett Pears. Journ. Agr. Research XIX: 10, Aug. 16, 1920, pp. 473-500.

PRELIMINARY INVESTIGATIONS, 1917, 1918

As a result of the first season's studies[2] an apparent correlation was found to exist between the time of picking and quality of fruit secured. Pears gathered early in the season not only shriveled considerably, which detracted from their general appearance, but were very poor in quality and lacked the distinctive characteristic flavor of the variety. These conditions were true with all varieties, including the Bartlett. No correlation, however, could be established between size of fruit and keeping quality, for both small and large specimens ripened at the same time. Moreover, it was noted that without apparent justification, there has been an increasing tendency among the growers of the Rogue River Valley to pick their crops earlier and earlier. This brings out the fact that size cannot at all be used as a guide in determining the stage of maturity or time of picking of the fruit. The potassium iodide test for starch, which for a while had been popular among the growers, was found to be very unreliable. Specific gravity tests with all the leading varieties of pears—Bartlett, Bosc, Anjou, Comice, Howell, Clairgeau—gave nothing of value. Chemical analyses for the amount of moisture, acid, and sugars were rather conflicting in results, showing no definite correlation between time of picking or eating quality and the changes in amount of moisture, acidity, and sugar content. As the chemical work was conducted under extremely unfavorable conditions, the fruit being shipped a distance of several hundred miles to the Station's chemical laboratory, these data cannot be considered indicative of the real chemical changes in pears at the time of picking or while in storage. The recent excellent investigations with Bartlett pears by Magness[1] give ample testimony to this effect.

To verify the records of the previous season, additional, more detailed evidence on the relative increase in size of Bartletts was secured in 1918[3]. It was found that throughout the season the fruit enlarged proportionally faster in transverse diameter than in the longitudinal. Consequently transverse diameter measurements may be used as a fair index of the relative changes in size of pears. In complete agreement with the results of the previous season, it was found that in no instance was size of the fruit a factor in ripening and decay. Seasonal differences in this respect were, however, very marked. Early-picked specimens were decidedly inferior in quality to those harvested on later dates, thus corroborating the observations of 1917. These facts emphasized once more the necessity of a test or unit of measurement of the maturity of the fruit.

The investigations in 1918 were extended also to a rather careful examination of the fruit for any possible morphological changes, other than size. The results were negative. So, too, all of the previously described tests, which at some time or other had been in vogue among the growers, were considered in turn and found to be untenable. Of the various new testing methods under investigation, a simple one, since then known as the "pressure test," gave, however, strikingly satisfactory and reliable results. Work extending through three additional seasons has furnished enough evidence that this is by far the most delicate and at the same time the most practical means of measuring the maturity of pears.

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[2] C. I. Lewis, J. R. Magness, and C. C. Cate. Preliminary Report of Pear Harvesting and Storage Investigations in the Rogue River Valley. Ore. Agr. Col. Exp. Sta. Bul. 154, 1918.

[3] C. I. Lewis, A. E. Murneek, and C. C. Cate. Pear Harvesting and Storage Investigations in the Rogue River Valley (Second Report). Ore. Agr. Col. Exp. Sta. Bul. 162, 1919.

THE "PRESSURE TEST" AS A MEASURE OF MATURITY OF THE PEAR

APPARATUS AND METHOD OF PROCEDURE

This new test is based upon the fact that during the growth and maturing of the pear, and for that matter of many other fruits, there is a gradual and consistent change in physical resistance to wounding or pressure of the cortex

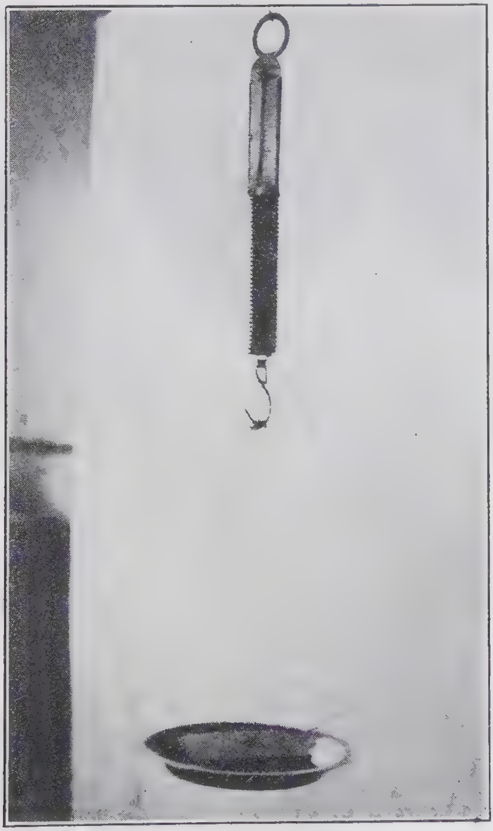

Fig. 1 Spring scale and pan used for testing pears in 1918.

or fleshy part of the fruit. To measure this change, a simple apparatus was constructed for the first year's preliminary work. It consisted of a steel ball, about one-half inch in diameter, half imbedded in a block of hard wood, which was then placed in a pan and attached to a spring scale (Fig. 1). The fruit was pressed slowly at the point of its largest diameter upon this ball till it came in contact with the wood. The amount of pressure required to penetrate the tissues was registered in pounds on the scale. It is readily seen that the principle of this method of testing is nothing but a modification of the common and popular practice of pressing one's thumb into a fruit to tell whether it is ready to eat. Crude as it may appear, it was found to be surprisingly delicate.

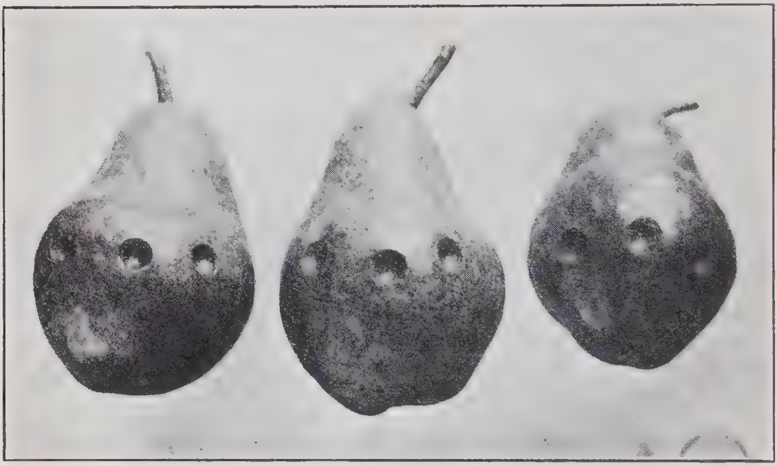

FIG. 2. Bartlett pears, showing position of pressure punctures.

Samples of fifteen pears, obtained from four typical orchards in the Rogue River Valley, were used on each day of testing. Every specimen was pressed three times and on one, the green side, only, thus eliminating to some extent any possible variation due to either structure of the tissues or cell contents (Fig. 2). This testing was done within six hours after picking the fruit. Altogether 180 readings were made on each day. Another series of records from the same specimens was obtained about twenty-four hours later by pressing again, three times, the adjoining parts of the fruit. The results being encouraging from the very start, the test was repeated at intervals of three days throughout the shipping season on both the Bartlett and Bosc varieties. All data of this first year's work may be found in detail in Oregon Agricultural College Experiment Station Bulletin 162[3].

During the following season a new and more convenient apparatus was constructed especially for this purpose. In principle it is similar to the one employed in 1918. Briefly it consists of a blunt, rounded plunger. one-half inch in diameter, running through a jacket and connected with a lever (Fig. 3). A movable ring, separated from the stationary jacket by a spring, runs over the top of the plunger to a definite distance when contact is made, causing an electric bell to ring. In operating this tester, fruit is placed in a padded stand on top of an ordinary family scale. The plunger then is pressed slowly by means of the lever, into the side of the fruit at the point of its greatest diameter. The plunger penetrates to a definite distance; i. e., till the bell rings. The weight required for this pressure is read on the scale. This apparatus has since been still further improved in mechanical detail (Fig. 4). During the seasons of 1919, 1920, and 1921, several thousand tests on all leading varieties of pears were made by means of this apparatus in the Rogue River and Willamette valleys. All fruit for this purpose was obtained from orchards exhibiting diverse conditions in physical character and moisture content of

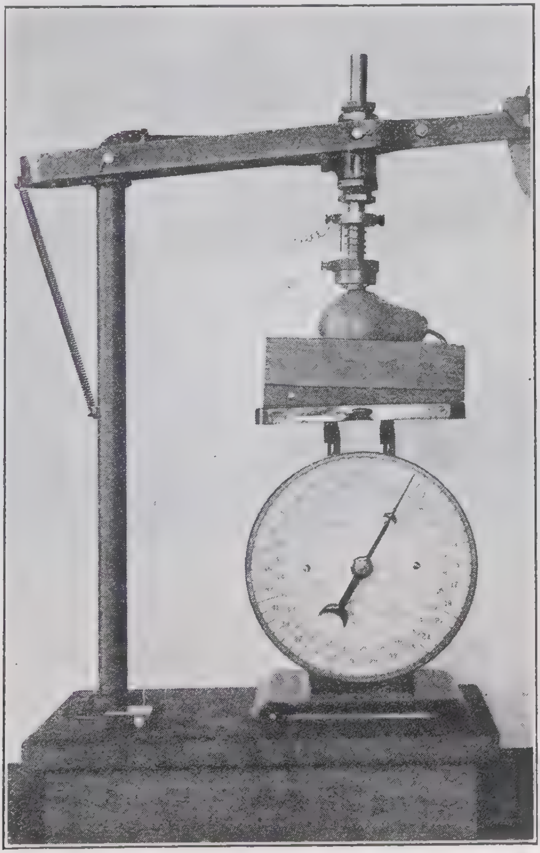

FIG. 3. The pressure apparatus.

the soil. The test has been found to be highly satisfactory and is now in use in a number of fruit-growing districts in Oregon and Washington.

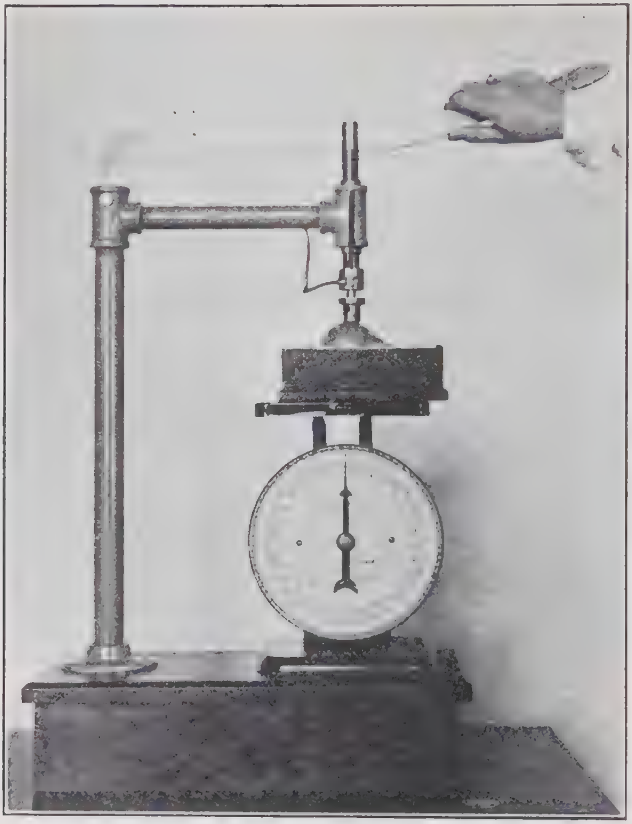

FIG. 4. Improved type of the pressure apparatus.

PRESENTATION OF DATA, BARTLETTS

No attempt will be made to give here all the detailed data on this work. Those wishing to see some such records are referred to an earlier publication of this Station[3], where summaries of pressure tests on each day of testing, as conducted in 1918, are given in detail. As examples, however, a number of tables are introduced here.

TABLE I. SAMPLE TABLES SHOWING VARIABILITY IN PRESSURE OF BARTLETT PEARS

Corvallis Orchard Company Orchard, Willamette Valley, 1920.

	Sept. 7			Sept. 11		
	Lbs.			*Lbs.*		
	34	33	33	30	30	29
	35	35	36	28	29	30
	36	35	35	33	35	32
	35	35	35	30	29	28
	32	32	33	33	33	33
	31	32	33	31	30	31
	35	34	34	32	32	33
	34	32	34	33	32	33
	35	34	35	33	32	33
	32	33	32	33	34	35
	36	35	36	30	31	30
	32	33	33	33	32	34
	36	35	36	32	33	34
	33	34	34	34	33	33
	33	35	33	32	32	33
Average	34	34	34	32	32	32

TABLE II. SAMPLE TABLE GIVING SUMMARY OF PRESSURE TESTS, BARTLETT PEARS

Bear Creek Orchard, Rogue River Valley, 1918.

	Ave. lbs.
(1) Picked 8/1:	
(a) Tested after 6 hours	35.0
(b) Tested after 30 hours	36.0
(2) Picked 8/2:	
(a) Tested after 6 hours	34.0
(b) Tested after 30 hours	36.0
(3) Picked 8/6:	
(a) Tested after 6 hours	33.0
(b) Tested after 30 hours	36.0
(4) Picked 8/8:	
(a) Tested after 6 hours	31.0
(b) Tested after 30 hours	32.0
(5) Picked 8/12:	
(a) Tested after 6 hours	30.0
(b) Tested after 30 hours	31.0
(6) Picked 8/15:	
(a) Tested after 6 hours	27.0
(b) Tested after 30 hours	29.0
(7) Picked 8/19:	
(a) Tested after 6 hours	26.0
(b) Tested after 30 hours	27.0
(8) Picked 8/22:	
(a) Tested after 6 hours	25.0
(b) Tested after 30 hours	25.5
(9) Picked 8/25:	
(a) Tested after 6 hours	24.5
(b) Tested after 30 hours	24.5
Number of lots	9
Number of fruits per lot	15
Number of pressure tests for each reading	45
Total number of pressure tests	810

TABLE III. SAMPLE TABLE GIVING SUMMARY OF PRESSURE TESTS, BARTLETT PEARS

Corvallis Orchard Company Orchard, Willamette Valley, 1920.

	Ave. lbs
(1) Picked 8/20:	
Tested after 6 hours	43
(2) Picked 8/23:	
Tested after 6 hours	42
(3) Picked 8/27:	
Tested after 6 hours	38
(4) Picked 8/30:	
Tested after 6 hours	37.5
(5) Picked 9/2:	
Tested after 6 hours	35
(6) Picked 9/7:	
Tested after 6 hours	34
(7) Picked 9/11:	
Tested after 6 hours	32
8) Picked 9/14:	
Tested after 6 hours	27.5
(9) Picked 9/17:	
Tested after 6 hours	20
Number of lots	9
Number of fruits per lot	15
Number of pressure tests for each reading	45
Total number of pressure tests	405

Table I is an example of two original record sheets of pressure tests on Bartletts taken from the same orchard on September 7 and 11, respectively. They are illustrative of the method of recording the condition of fruit on a certain day. It is seen that each lot contained fifteen pears and that every fruit was tested three times. Thus in each case forty-five readings were taken as an average unit of the condition of fruit in that particular orchard on a certain date. Naturally, as may be expected of organic forms, considerable variation is exhibited by the different specimens and some variation even within an individual fruit. On condensing to a summary a number of readings this variation, however, is effectively overcome.

Tables II and III are introduced as typical examples of summaries of pressure tests of fruit taken throughout the season from the various orchards. In the case of those of the Bear Creek orchard, in 1918 (Table II), it is to be noted that each lot was tested twice, 6 hours and 30 hours, respectively, after picking. As it was soon learned that data obtained within 6 hours after procuring the fruit were much more reliable than those taken a day later, only the former were considered during the last two seasons of the investigation. This is shown in Table III, giving summary of pressure tests of Bartletts in the Corvallis Orchard Company orchard in 1920.

The summaries of results of all tests on Bartlett pears in 1918 to 1921, inclusive, are presented in Tables IV to VIII.

TABLE IV. GENERAL SUMMARY OF PRESSURE TESTS, BARTLETT PEARS
Approximately 6 hours after picking.
Rogue River Valley, 1918.

Lot No.	Date	Orchard				Average	Shipping season
		Fiero	Bear Creek	Hillcrest	Speck		
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	
(1)	August 1	35.0	35.0	33.5	30.0	34.50	↑
(2)	August 2	33.0	34.0	......	......	32.40	
(3)	August 5-6	32.0	33.0	31.0	28.0	31.20	
(4)	August 8-9	31.0	31.0	30.0	28.0	30.05	
(5)	August 12	30.0	30.0	29.0	28.0	29.20	
(6)	August 15	29.0	27.0	28.5	26.0	27.80	
(7)	August 19-20	27.0	26.0	25.0	24.5	25.40	
(8)	August 22	25.5	25.0	24.0	23.0	24.40	
(9)	August 26	25.0	24.5	24.0	24.0	24.30	
(10)	August 29	......	......	......	20.0	......	
(11)	August 31	......	......	25.0	......	......	↓
(12)	September 3	......	......	24.0	......	......	
(13)	September 5	......	......	24.0	......	......	
(14)	September 12	......	......	20.5	......	......	
(15)	September 16	......	......	18.0	......	......	

TABLE V. GENERAL SUMMARY OF PRESSURE TESTS, BARTLETT PEARS
Approximately 6 hours after picking.
Rogue River Valley, 1919

Lot No.	Date	Orchard					Average	Shipping season
		Hillcrest	Mc-Creadie	Bear Creek	Car-penter	So. Ore. Ex. Sta.		
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	
(1)	Aug. 2	36.0	34.5	37.0	35.0	36.0	35.7	↑
(2)	Aug. 4	36.0	32.5	36.5	34.5	36.0	35.1	
(3)	Aug. 6	35.5	33.5	35.5	35.5	35.5	35.1	
(4)	Aug. 8	35.5	31.0	35.0	35.5	33.0	34.0	
(5)	Aug. 11	32.5	29.5	32.0	33.5	33.0	32.1	
(6)	Aug. 13	33.0	29.0	32.0	32.5	32.0	31.7	
(7)	Aug. 15	32.5	28.5	31.5	33.5	32.5	31.7	
(8)	Aug. 18	32.0	28.0	30.0	31.0	31.5	30.5	
(9)	Aug. 22	31.5	27.5	29.0	30.0	29.0	29.4	
(10)	Aug. 25	28.5	27.0	27.0	28.5	28.0	27.8	
(11)	Aug. 29	25.5	......	26.5	27.0	27.0	26.5	↓

TABLE VI. GENERAL SUMMARY OF PRESSURE TESTS, BARTLETT PEARS
Approximately 6 hours after picking.
Willamette Valley, 1920.

Lot No.	Date	Orchard				Average	Shipping season
		Sheak	Reed	Corvallis Orchard Co. Hill	Corvallis Orchard Co. Bottom		
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	
(1)	Aug. 20	38.0	42.5	43.0	39.5	40.8	
(2)	Aug. 23	34.0	41.5	42.0	36.5	38.5	
(3)	Aug. 27	35.0	40.5	38.0	36.5	37.5	
(4)	Aug. 30	33.5	39.5	37.5	36.5	36.7	↑
(5)	Sept. 2	33.0	37.5	35.0	32.5	34.5	
(6)	Sept. 7	30.0	36.5	34.0	32.5	33.2	
(7)	Sept. 11	29.5	34.5	32.0	30.5	31.6	
(8)	Sept. 14	24.0	......	27.5	30.0	27.2	
(9)	Sept. 17	18.5	......	20.0	......	19.2	↓

TABLE VII. GENERAL SUMMARY OF PRESSURE TESTS, BARTLETT PEARS

Approximately 6 hours after picking.
Willamette Valley, 1921.

Lot No.	Date	ORCHARD			Average	Shipping season
		Sheak	Corvallis Orchard Co. Hill	Corvallis Orchard Co. Bottom		
		lbs.	*lbs.*	*lbs.*	*lbs.*	
(1)	Aug. 11	41.0	40.5	41.5	41.0	
(2)	Aug. 16	37.0	37.5	35.5	36.7	
(3)	Aug. 19	35.5	37.5	35.5	36.2	↑
(4)	Aug. 23	33.0	33.0	35.5	33.8	
(5)	Aug. 26	31.5	32.0	33.0	32.2	
(6)	Aug. 30	29.5	31.5	32.0	31.0	
(7)	Sept. 2	29.5	31.0	32.0	30.8	
(8)	Sept. 6	27.5	29.5	31.0	29.3	

TABLE VIII. SUMMARY OF PRESSURE TESTS, BARTLETT PEARS, 1918 AND 1919

Six hours and thirty hours after picking.

1918

Lot No.	Date	Average 6 hours	Average 30 hours
		lbs.	*lbs.*
(1)	Aug. 1	34.50	
	Aug. 2		37.7
(2)	Aug. 2	32.40	
	Aug. 3		34.7
(3)	Aug. 5–6	31.20	
	Aug. 6–7		33.7
(4)	Aug. 8–9	30.05	
	Aug. 9–10		30.7
(5)	Aug. 12	29.20	
	Aug. 13		30.0
(6)	Aug. 15	27.80	
	Aug. 16		29.2
(7)	Aug. 19–20	25.40	
	Aug. 20–21		25.6
(8)	Aug. 22	24.40	
	Aug. 23		24.7
(9)	Aug. 26	24.30	
	Aug. 27		24.0

1919

Lot No.	Date	Average 6 hours	Average 30 hours
		lbs.	*lbs.*
(1)	Aug. 2	35.7	
	Aug. 3		37.4
(2)	Aug. 4	35.1	
	Aug. 5		37.3
(3)	Aug. 6	35.1	
	Aug. 7		36.8
(4)	Aug. 8	34.0	
	Aug. 9		36.3
(5)	Aug. 11	32.1	
	Aug. 12		33.3
(6)	Aug. 13	31.7	
(7)	Aug. 15	31.7	
	Aug. 16		31.8
(8)	Aug. 18	30.5	
	Aug. 19		30.2
(9)	Aug. 22	29.4	
	Aug. 23		29.6
(10)	Aug. 25	27.8	
	Aug. 26		27.7

It should be noted that during each season pears from several representative orchards have been taken into consideration and that the testing was done at close, usually three-day intervals. These tables give at a glance the general changes in resistance to pressure of Bartlett pears from a particular orchard in a certain year and also, by summarizing these results, the average seasonal changes in a section, in these cases the Rogue River Valley for 1918 and 1919, and the Willamette Valley for 1920 and 1921. Difference in response to this test when records were taken approximately 6 to 30 hours, respectively, after picking are shown in Table VIII.

In order to learn of the existence of a possible correlation between general increase in size and differences in resistance to pressure, diameter measurements were taken of all Bartlett pears used for testing in 1918-1920. These are given in Tables IX to XI. This information is of particular importance, since, as previously stated, the orchardist is often guided by size in his determinations of the time of picking the crop.

TABLE IX. DIAMETER MEASUREMENTS OF BARTLETT PEARS
Rogue River Valley, 1918.

Lot No.	Orchard				Average
	Fiero	Bear Creek	Hillcrest	Speck	
	in.	*in.*	*in.*	*in.*	*in.*
(1)	2.09	2.19	2.07	2.20	2.12
(2)	2.28	2.31	......	2.20	2.26
(3)	2.24	2.23	2.15	2.17	2.20
(4)	2.27	2.29	2.21	2.31	2.27
(5)	2.41	2.38	2.28	2.34	2.35
(6)	2.43	2.47	2.28	2.39	2.39
(7)	2.61	2.55	2.33	2.59	2.52
(8)	2.68	2.61	2.32	2.49	2.52
(9)	2.56	2.64	2.36	2.58	2.53
(10)	......	......	......	2.46	......
(11)	......	......	2.25	......	......
(12)	......	......	2.32	......	......
(13)	......	......	2.31	......	......
(14)	......	......	2.30	......	......
(15)	......	......	2.29	......	......

TABLE X. DIAMETER MEASUREMENTS OF BARTLETT PEARS
Rogue River Valley, 1919.

Lot No.	Orchard					Average
	Hillcrest	McCreadie	Bear Creek	Carpenter	So. Ore. Exp. Sta.	
	in.	*in.*	*in.*	*in.*	*in.*	*in.*
(1)	2.33	2.35	2.28	2.22	2.42	2.32
(2)	2.28	2.39	2.35	2.25	2.55	2.36
(3)	2.32	2.39	2.36	2.33	2.62	2.40
(4)	2.36	2.47	2.43	2.37	2.58	2.44
(5)	2.34	2.55	2.38	2.36	2.77	2.48
(6)	2.43	2.53	2.41	2.40	2.82	2.52
(7)	2.40	2.52	2.33	2.44	2.72	2.48
(8)	2.48	2.49	2.43	2.57	2.77	2.55
(9)	2.46	2.57	2.44	2.34	2.81	2.52
(10)	2.43	2.32	2.51	2.43	2.94	2.53
(11)	2.51	......	2.54	2.59	2.97	2.65

TABLE XI. DIAMETER MEASUREMENTS OF BARTLETT PEARS

Willamette Valley, 1920.

Lot No.	Orchard				Average
	Sheak	Reed	Corvallis Orchard Co. Hill	Corvallis Orchard Co. Bottom	
	in.	*in.*	*in.*	*in.*	*in.*
(1)	2.46	2.47	2.33	2.46	2.43
(2)	2.34	2.49	2.42	2.42	2.42
(3)	2.34	2.43	2.51	2.48	2.46
(4)	2.30	2.60	2.70	2.53	2.53
(5)	2.40	2.52	2.63	2.47	2.50
(6)	2.42	2.54	2.63	2.65	2.56
(7)	2.43	2.68	2.72	2.67	2.62
(8)	2.53	....	2.52	2.64	2.56
(9)	2.39	....	2.80	....	2.59

DISCUSSION OF RESULTS

Judging from the results obtained during the four seasons, it is quite evident that a distinct correlation exists between the stage of maturity of a Bartlett pear and resistance to physical pressure of the outer regions of the fruit, the tissues of epidermis and cortex. The data each year show a really remarkable consistence in this respect. The minor variations of individual orchards may be easily explained by variations in collecting the different lots on each day of testing. Though the fruit was usually obtained from the same tree, naturally no two successive collections were made up of specimens that were similarly situated on the tree or had a like exposure. Moreover, it was found by actual experience that any injury to the fruit, such as limb rubs, attacks of insects or fungi, had a considerable effect upon the physical conformation or physiological condition of the tissues and hence upon the response to a physical test of this kind. So, too, the amount of russeting and red pigment or "blush" produced a marked difference in this respect. Though such specimens were eliminated as much as possible, some of them perforce had to be used.

A point of much greater significance is illustrated by the fact that there is a consistent difference in the stage of maturity, as determined by this test, of Bartletts obtained from the same orchard. Thus, fruit from the Speck orchard, in 1918, was much riper throughout the season than that from the other orchards (Table IV). The same was true of McCreadie orchard in 1919 (Table V), and the Sheak orchard in 1920 and 1921 (Tables VI and VII). While it is commonly known that because of location, exposure, soil conditions, moisture, and other factors, fruit will ripen in one orchard a number of days earlier than in another, though the orchards be in close proximity, no definite estimation of such differences has ever been made. The pressure test will clearly show these environmental differences. In this respect it appears of undoubted value.

As viewed from Table VIII, pressure tests taken within 6 hours after picking are distinctly more reliable than those recorded 24 hours later. Fruit used for this second set of data was kept at ordinary room temperature. The weather being usually warm during the shipping season, the epidermis and cortex were naturally affected, resulting in a marked increase in resistance to the same pressure. As the season progressed, increase in pliability of the epidermis resulting in greater increase in resistance was partly and later totally overcome by a rapid increase in ripeness of the tissues of the cortex. This is graphically illustrated in Fig. 5. Towards the end of the season, pears kept at ordinary room temperature until the next day were considerably riper than those recently picked and tested within 6 hours. This brings out the important point that no fruit procured the day before can be used with reliability for this kind of testing, while freshly picked specimens, tested shortly after picking, are entirely satisfactory. This is of particular significance at the end of the harvesting season.

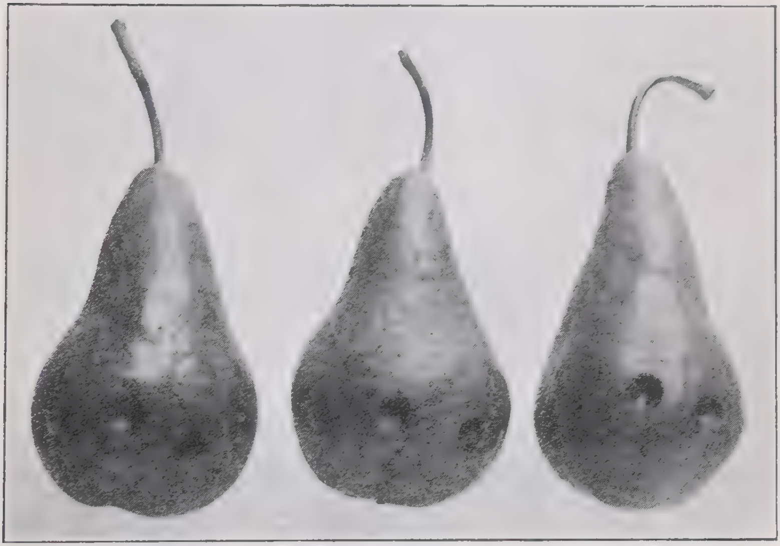

FIG. 6. Bosc pears, showing position of pressure punctures

Although there is naturally a fairly gradual increase in the transverse diameter of Bartletts at the time the tests were made, this change in size is not at all consistent for either the specimens on the same tree, the same orchard, or between two orchards under consideration (Tables IX-XI). In other words, no definite correlation was found to exist between the increase in diameter of fruit and the gradual and definite lowering of resistance to pressure. In order to add still further information on this question, a double amount of fruit was used in 1918. The fruit was grouped into two lots, each representing average extremes in diameter. No difference in resistance was noted. This result agrees with the facts brought forth in connection with our storage work with pears [2 3], when it was found that both small and large pears of the same variety ripened and decayed at the same time.

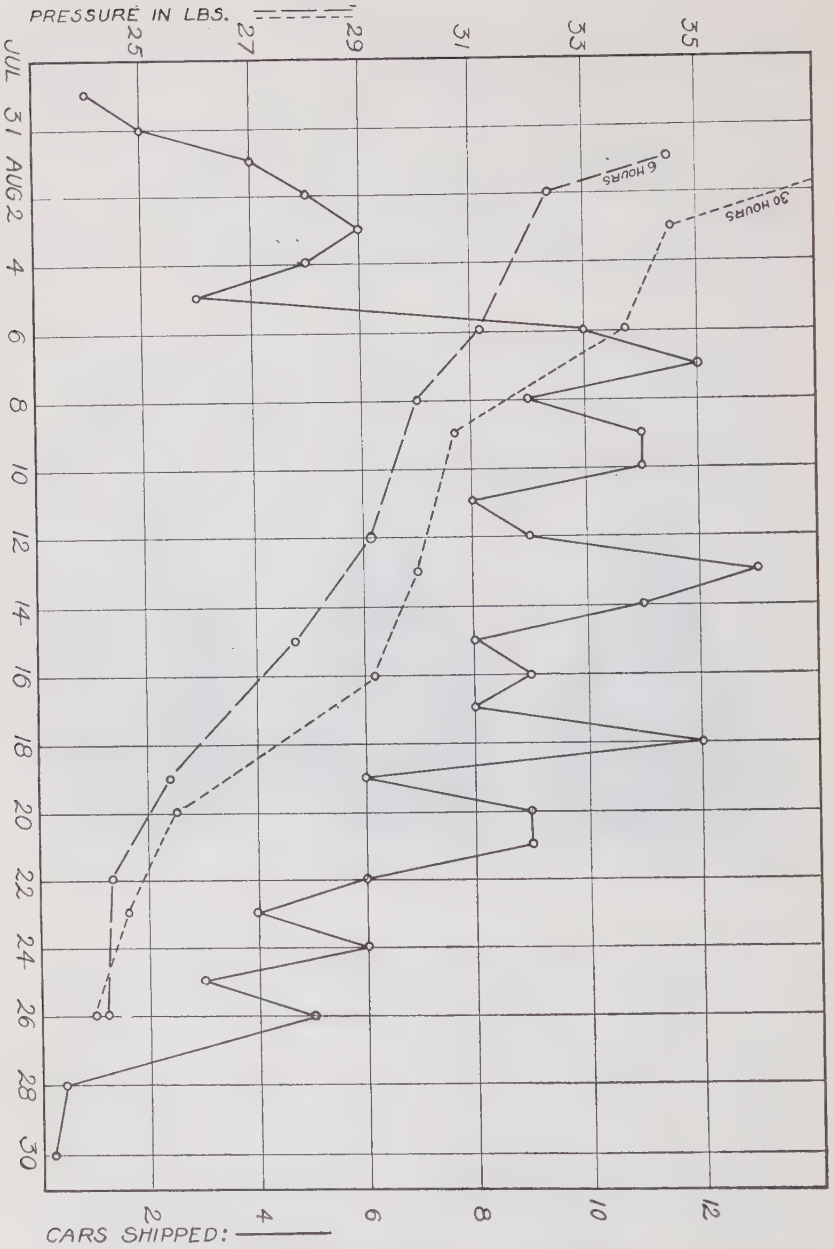

Fig. 5. Graph showing approximate number of cars of Bartlett pears shipped from Medford Oregon, in 1918 and records of pressure tests for that season.

TESTS OF OTHER VARIETIES

Bosc. To find whether such a test would be applicable to other varieties beside the Bartlett, it was used on practically all leading commercial fall pears. The Bosc, for instance, was tested in a similar way during its picking and shipping season (Fig. 6). In both 1918 and 1919, fruit was obtained from four representative orchards, and tested at three- and four-day intervals.

TABLE XII. GENERAL SUMMARY OF PRESSURE TESTS, BOSC PEARS
Rogue River Valley, 1918.

Lot No.	Date	Orchard				Average
		Bear Creek	Hillcrest	Kenly	Hollywood	
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*
(1)	Aug. 22	25.2	24.0	26.7	25.3	25.3
(2)	Aug. 26	24.0	24.5	27.3	25.0	25.2
(3)	Aug. 28	24.7	23.5	26.3	24.2	24.7
(4)	Aug. 31	24.5	24.5	25.5	24.2	24.7
(5)	Sept. 3	23.5	22.7	24.2	23.2	23.4
(6)	Sept. 7	22.5	23.3	25.0	23.0	23.4
(7)	Sept. 16	...	23.3	...	20.2	21.7
(8)	Sept. 19	...	21.5	...	20.2	20.8

TABLE XIII. GENERAL SUMMARY OF PRESSURE TESTS, BOSC PEARS
Rogue River Valley, 1919.

Lot No.	Date	Orchard				Average
		Hill	Willard	Hillcrest	So. Ore. Exp. Sta.	
		lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*
(1)	Aug. 18	29.0	28.5	29.0	29.5	29.0
(2)	Aug. 25	28.0	28.5	28.0	29.0	28.4
(3)	Aug. 28	26.5	27.0	26.0	25.5	26.2
(4)	Sept. 1	24.5	27.0	25.0	25.0	25.4
(5)	Sept. 4	25.0	26.5	24.5	25.5	25.4
(6)	Sept. 8	23.0	25.0	23.0	24.5	23.9
(7)	Sept. 11	23.0	24.0	22.5	23.5	23.2
(8)	Sept. 15	22.0	22.5	21.5	23.5	22.4
(9)	Sept. 18	21.0	23.0	22.0	22.0	22.0

The results obtained were very much like those of the Bartlett. This is true both in respect to individual orchards and the general averages for the season. The decline in resistance to pressure is, however, not nearly so rapid in the case of the Bosc, though quite uniform and consistent. The difference of the two varieties in this respect is evidently due to a much slower ripening of the Bosc and to the rougher character of the epidermis.

Howell, Anjou, Comice, Winter Nelis. While no special study was made of other commercial varieties, a number of samples of Howell, Anjou, Comice, and Winter Nelis were tested as they were brought in unsolicited by growers during the commercial season in 1919. These samples in each case consisted of but a few fruits, in many instances half a dozen or less. So, too, on some dates a number of samples were used to draw an average for that particular day, while on others, there was only one sample to be considered. And naturally the fruit came from a large number of orchards. Thus in the case of Howell pears, eight orchards were involved; Anjou, eleven; Comice, ten; Winter Nelis, ten. It is surprising that even under such diverse conditions, the results have been so uniform. More consistent evidence is obtained when pears coming from a single orchard are considered, in this case two lots of Anjous. Note the uniformity in change of maturity as measured by the pressure test (Table XVI). The considerable fluctuations in Tables XV and XVII are readily explainable by the close, often daily, intervals of testing and the great variation in the number of samples considered on the respective dates. Accordingly it would appear that this test might be successfully used on all pears. But because of the comparatively much coarser nature of the epidermis of some of the fall varieties and the more gradual changes in maturity, the differences are not so pronounced as with the Bartlett.

TABLE XIV. SUMMARY OF PRESSURE TESTS, HOWELL PEARS
Rogue River Valley, 1919.

Date	Aug. 8	Aug. 9	Aug. 11	Aug. 15	Aug. 18	Aug. 25	Aug. 29
Average lbs	31	29.5+	29.5—	29	28	26	24
No. of samples	3	3	4	3	1	1	1

TABLE XV. SUMMARY OF PRESSURE TESTS, ANJOU PEARS
Rogue River Valley, 1919.

Date	Aug. 20	Aug. 22	Aug. 27	Aug. 28	Aug. 29	Aug. 30	Sept. 2	Sept. 6	Sept.10	Sept. 15
Average lbs	26	27.5	24.5	25.8	25	23.5	23.8	22.2	22.2	18.5
No. of samples	1	2	2	3	6	1	6	2	2	1

TABLE XVI. PRESSURE TESTS, ANJOU PEARS FROM INDIVIDUAL ORCHARDS

Orchard		**Dillon Hill, 1919.**			
Date		August 28	September 2	September 10	September 15
Average lbs		26	23	22.5	18.5
Orchard		**Corvallis Orchard Co., 1920.**			
Date	September 7	September 11	September 17	September 21	October 7
Average lbs	35.5	34	31	30	28.5

TABLE XVII. SUMMARY OF PRESSURE TESTS, COMICE PEARS
Rogue River Valley, 1919.

Date	Aug. 28	Aug. 29	Aug. 30	Sept. 1	Sept. 2	Sept. 4	Sept. 6	Sept.10	Sept.15	Sept. 25
Average lbs	22.2	21.5	19.5	19.0	19.2	19.5	19.0	18.2	16.9	16.5
No. of samples	3	1	1	4	2	2	3	3	4	1

TABLE XVIII. SUMMARY OF PRESSURE TESTS, WINTER NELIS PEARS
Rogue River Valley, 1919.

Date	Sept. 10	Sept. 12	Sept. 15	Sept. 18	Sept. 19	Sept. 20
Average lbs	28.5	29	27.3	28.5	26.2	26
No. of samples	1	1	5	2	2	2

Apples. The few trials with apples show, too, that the use of this method of determination of the stage of maturity may be applied to this fruit also. While only two varieties of apples have been taken into account, the results are quite indicative. Table XIX shows that Grimes, for example, changed in resistance to pressure, between September 7 and 23, from 31.5 to 28 pounds, and Wagener, between September 11 and 23, from 29 to 24.5 pounds. The dates include the harvesting periods of the two varieties.

TABLE XIX. PRESSURE TESTS, APPLES
Willamette Valley, 1920.

Grimes	**Corvallis Orchard Company, 1920.**			
Date	September 7	September 11	September 14	September 23
Average lbs	31.5	29	28	28

Wagener	**Corvallis Orchard Company, 1920.**		
Date	September 11	September 14	September 23
Average lbs	29	26.5	24.5

PRACTICAL APPLICATION

Determination of Time of Harvesting of Bartletts. The question naturally arises as to the real practical value of the tests. The foregoing investigations with almost all commercial varieties of pears, but particularly with the Bartlett, show that the pressure test, because of its sensitivity and simplicity, may find the greatest practical application in determining the time of harvesting of a particular variety of fruit. As may be viewed from the records, the condition of maturity of Bartletts during the harvesting season may be expressed by a gradual lowering in resistance to this type of pressure of from 35 to 25 pounds, or possibly less, a change of approximately half a pound a day. To prevent shriveling and realize a better quality, no fruit, even for the most distant eastern markets, should be picked when registering much over 35 pounds. As the season progresses the resistance will naturally decrease until at the end of commercial shipping it will be, or should be, close to 25 pounds. This is well illustrated in Fig. 7, where data for 1918 and 1919 are expressed in graphical form. The shipping periods coincided almost to a day during the two seasons, hence the pressure graphs for 1918 and 1919 are plotted against the shipping curve of 1919 only. It will be noted that in 1918 during the harvesting time, Bartletts registered 34.5 to 25.8 pounds, while in 1919, the range was from close to 36 to 26.5 pounds. Thus one sees at a glance that though the dates of the seasons practically coincide, the fruit was shipped greener in 1919 than in 1918; the season had been advanced about a week. The shaded portion of Fig. 7 indicates quite clearly this difference. It also points out a possible seasonal variation, or the latitude of range of the test.

Bartlett pressure records for 1920 and 1921 (Tables VI and VII) show also that the shipping season extended from somewhere around 35 to close to 25

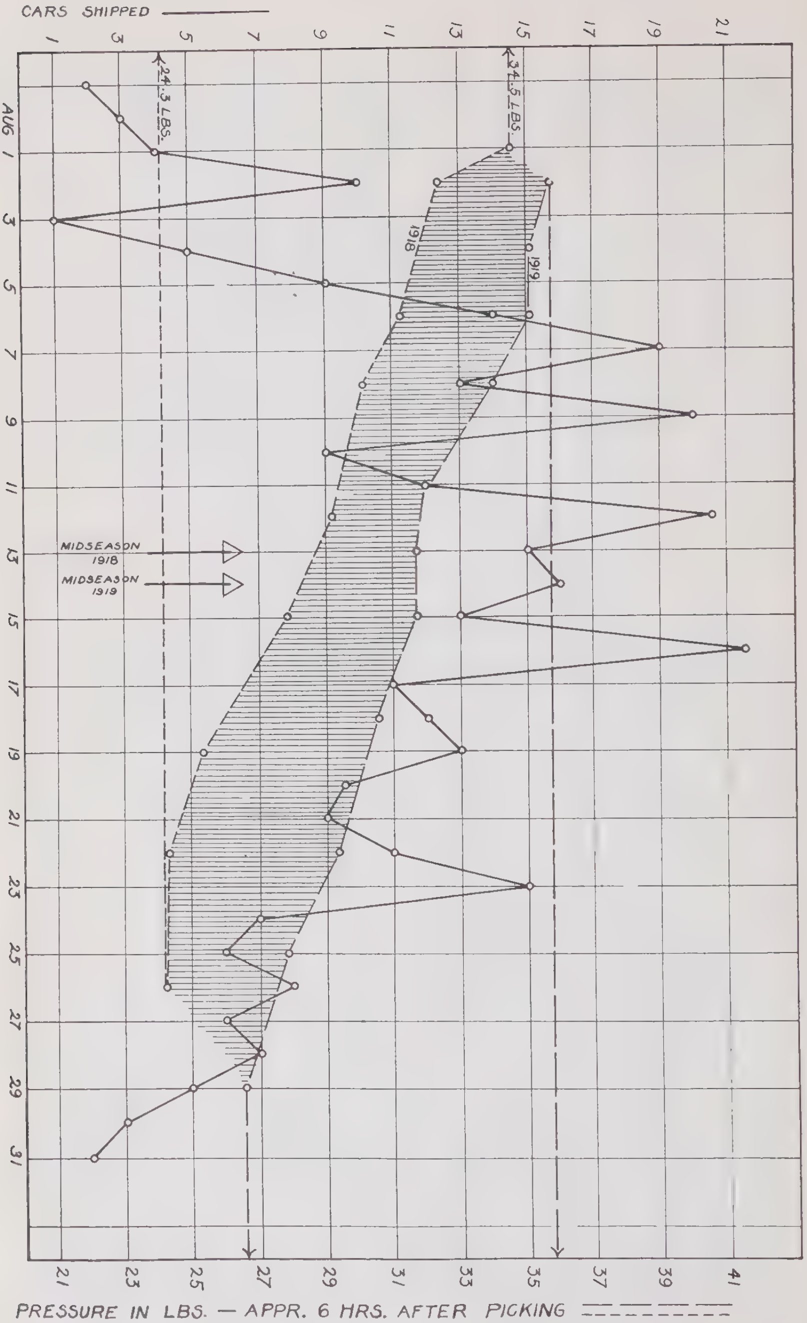

Fig. 7. Graph showing approximate number of cars of Bartlett pears shipped from Medford, Oregon, in 1919, and records of pressure tests for 1918 and 1919.

pounds. But because of the extent of the Willamette Valley and the comparatively few scattered shipments of fresh fruit, it is somewhat difficult to obtain exact reliable information on the harvesting of Bartletts. The data are, however, so closely identical to those of the Rogue River Valley that they hardly solicit questioning.

A word may be in place here regarding that part of the crop destined for the fruit-products plant. For the drying and canning trade it is entirely safe to keep Bartlett pears on trees till they register as close to 25 pounds as possible, and under certain circumstances, even less. It is the firm belief of many growers that the fruit is usually picked too green. But how green? How long can one safely permit fruit to hang on the trees? These questions can be answered only by a reliable test. So, too, after the pears have been picked and in the hands of the cannery man, it would be well if he also should follow carefully the changes in maturity of the fruit in storage. The pressure test, intelligently administered, would undoubtedly prevent the often-occurring losses of Bartletts in storage. There is no logical reason why it should not be just as easy to determine the exact stage when this variety should be canned or dried as when it should be harvested.

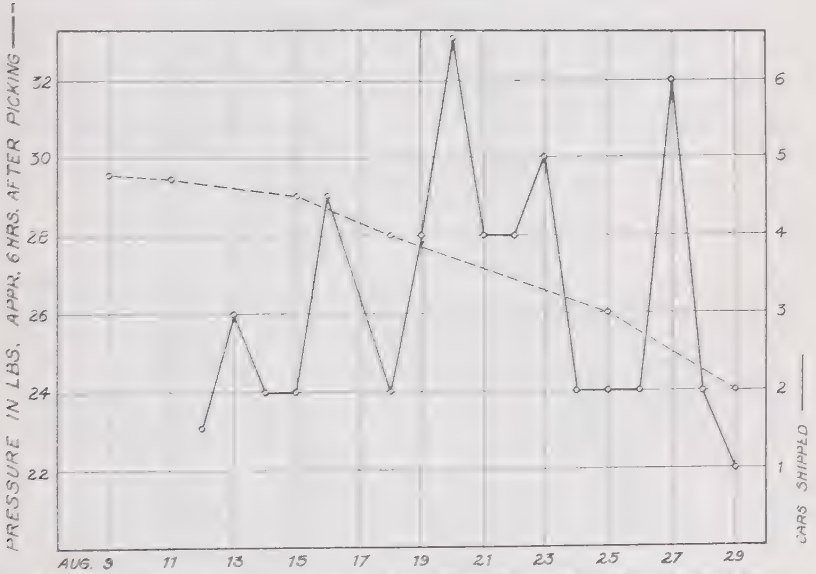

Fig. 8. Graph showing approximate number of cars of Howell pears shipped from Medford, Oregon, in 1919, and records of pressure tests for that season.

Determination of Time of Harvesting of Fall Pears. The pressure test is applicable to other varieties beside the Bartlett. Fig. 9 illustrates the condition of Bosc at the time of harvesting in 1918 and 1919. The pressure record curves are plotted against the shipping curves of the two seasons. It shows that this variety was picked when it registered 26 to 20 pounds or possibly less. In 1918, Bosc pears were harvested in a much greener condition than in 1919. These results show that this variety can be safely picked for the

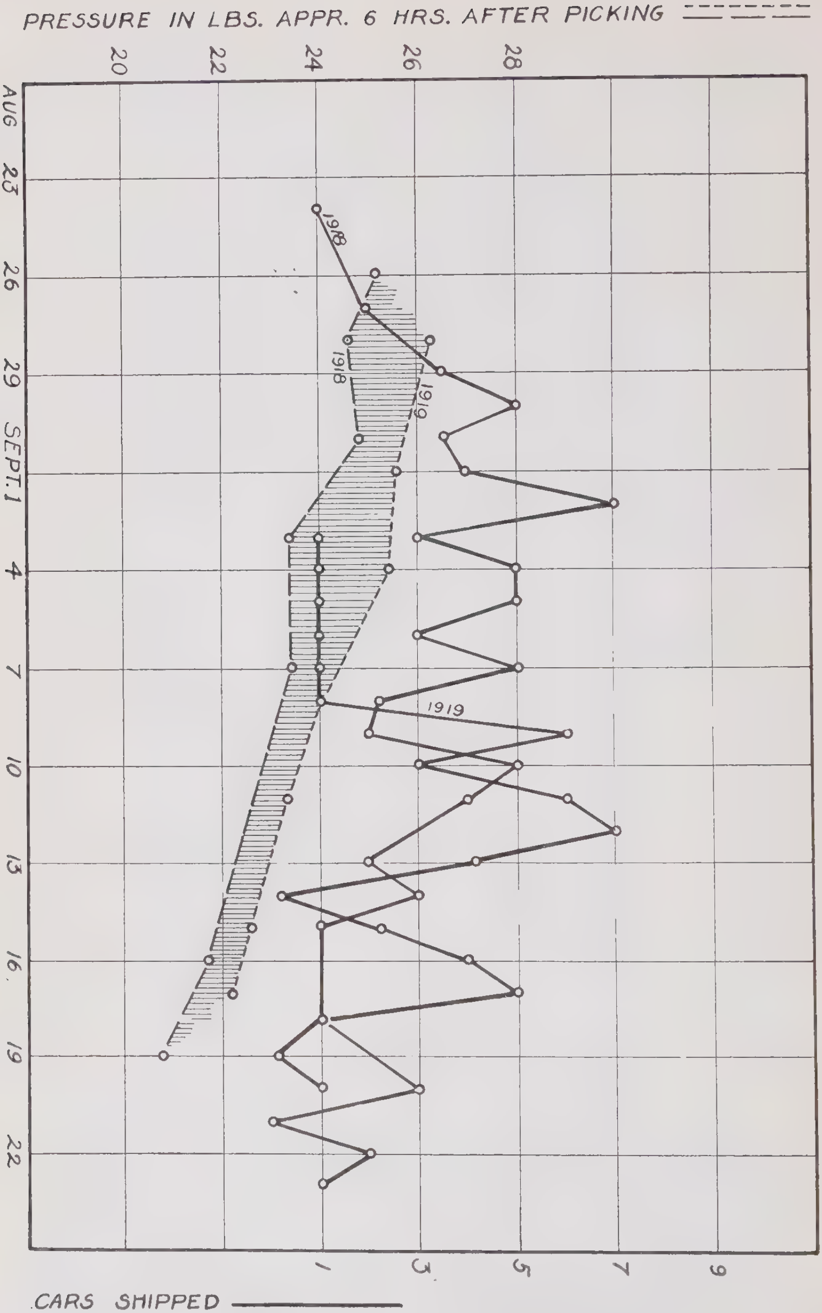

Fig. 9. Graph showing approximate number of cars of Bosc pears shipped from Medford, Oregon, in 1918 and 1919 and records of pressure tests for the two seasons.

most distant markets within the limits of resistance to this pressure of from 24 to 20 pounds. Early picked lots of Bosc are distinctly poorer in quality than those of a fair degree of maturity.

Different pressure figures were obtained when Howells were tested (Fig. 8). This variety shows a change in maturity during the shipping season of 1919 of 29.5 to 24 pounds, approaching in this respect much more the condition of the Bartlett. At the height of shipping, Howells registered 27 pounds. It is rather unfortunate that, because of financial limitations of the Station, the investigation could not be extended over a number of seasons so as to include all the leading fall pears.

The Value of a Unit of Measurement of Maturity of the Pear. The value of such a unit of measurement as has been introduced by this test is self-evident. As the condition of the various shipments of fruit is more or less known at the eastern markets, both at time of arrival and during the short period of marketing, one can quite readily tell what may be expected in respect to keeping or eating quality of a shipment of Bartletts that registers, say 30 pounds on the average. Here then we have a tangible unit of measurement of the exact stage of maturity of the fruit at the time it was picked and shipped. Surprising as this may be, the test is as sensitive and reliable as any that has been used. Considering the very close, even daily, intervals at which it has been demonstrated to show differences in maturity and the convenience with which it may be handled, it is questioned if any of our present chemical methods of analysis would afford a more delicate means to determine such changes as may have taken place in a very short time in the fruit, and could at the same time be as convenient and practical as this test.

It is to be understood, of course, that the unit of measurement, as expressed in pounds of pressure, is but comparative and directly dependent upon the volume of the hemisphere forming the tip of the plunger. (In the case of this apparatus it is one-half inch in diameter). So, too, seasonal variations in either direction are to be expected. Again it must be emphasized that economic factors will continue to determine to a large extent the time of shipping and marketing and therefore frequently work against any considerations resulting from such a test.

Increase in Diameter and Weight, Bartletts. A point of particular interest to the growers is the question as to what percent of increase in tonnage may be expected when Bartletts, for instance, are kept a number of days longer on the trees than it is the common practice to do, the pressure test being used to determine the condition of the fruit. This information is of great economic value in instances where the crop is to be used for either drying or canning. Hence a study of the increase in size of Bartletts was conducted in 1918 and again in 1921. The resultant data show that this variety increases gradually in size, but at an accelerated rate, during the time of the development of the fruit. The transverse diameter was found to be a ready though not an absolute index of the increments in size[3]. Because of technical difficulties, the proportional increase in weight was not determined in 1918. During the harvesting season in 1921, however, both the average diameter and weight of several lots of Bartletts were carefully recorded. It was found that an average increase in diameter from approximately 2 inches (2.06 inches) to 2¼ inches (2.24 inches) resulted in an approximate increase in weight of close to 35 percent (32.1 percent). Again an increase in diameter of 2¼ inches (2.24 inches) to 2¾ inches (2.68 inches) brought about an average increase in weight of approximately 75 percent (71.1 percent). The ratio of percent increase in weight to percent increase in diameter was found to be 1:3.7 and 1:3.6, respectively (Table XX).

TABLE XX. INCREASE IN SIZE AND WEIGHT OF BARTLETT PEARS, 1921

Number of determinations	Average diameter (inches)	Average weight (ounces)	Percent increase		Ratio
			Diameter	Weight	
88	2.06	3.30	....	....	....
80	2.24	4.36	8.7	32.1	1: 3.7
67	2.68	7.46	19.8	71.1	1: 3.6
Oaco Orchard, 1921.					
Aug. 22........	2.31	4.77	....	....	....
Aug. 31	2.49	5 92	7.8	24 1	1: 3 1

Measurements of increases in both diameter and weight of the same specimens were secured from Bartletts in 1921. Thus in nine days between August 22 and August 31, at the time of picking, there was an increase of 7.8 percent in transverse diameter and 24.1 percent in weight, the ratio being 1:3.1. Here then we have a reliable approximation as to what increase in tonnage may be expected of Bartletts in a certain number of days at harvesting time.

That a close correlation exists between increase in transverse diameter and increase in weight is to be expected. This is shown in Table XXI.

TABLE XXI. COEFFICIENT OF CORRELATION* BETWEEN TRANSVERSE DIAMETER AND WEIGHT OF BARTLETT PEARS

Oaco Orchard, 1921.

Aug. 22	..................0 935 ±0.006
Aug. 31	...0 948 ±0.006

---

* Formula used: $r = \frac{\Sigma DwDd}{n \sigma w \sigma d}$ Where *w* represents weight in ounces and *d* diameter in inches

$$Er = \pm \frac{0.6745\ (1-r^2)}{\sqrt{n}}$$

Additional data, taken from a number of lots of Bartletts showed that the ratio of percent increase in diameter to percent increase in weight was very close to 1:3.5. Using this factor as a basis, the percent increase in weight during seven-and fourteen-day intervals was calculated from diameter measurements of Bartletts taken in Rogue River Valley, 1918[3].

TABLE XXII. SEASONAL INCREASE IN TRANSVERSE DIAMETER AND CALCULATED PERCENT INCREASE IN WEIGHT OF BARTLETT PEARS

Bear Creek, Speck and Fiero Orchards, Rogue River Valley, 1918.

Date	Number of determinations	Average diameters (inches)	7-day increments	Percent increase		14-day increments	Percent increase	
				Diameter	Weight (x 3.5)		Diameter	Weight (x 3.5)
July 20...	246	1.89						
July 27 .	245	2.02		6.8	23.8			
Aug. 2. .	244	2.12		5.0	17.5		12.2	42.7
Aug. 9. .	229	2.22		4.7	16.4		9.9	34.6
Aug. 16. .	210	2.32		4.5	15.7		9.4	32.9
Aug. 23...	200	2.42		4.3	15.0		9.0	31.5
			Average (7 days)..	5.1	17.7	Average (14 days).	10.1	35.4

A study of Table XXII will make it clear that under average conditions an enlargement of 5.1 percent in transverse diameter corresponding to an increase of 17.7 percent in weight may be expected to accrue every seven days, while such average increase in a fourteen-day period would be 10.1 percent and 35.4 percent, respectively. These calculated figures agree very closely with the actual weighed increase of Bartletts in 1921 (Table XX).

Some exceptions should be introduced here. Instances have come to observation where pears on trees growing in particularly dry locations will not have an even and uniform increase in size because of deviation from the normal form of the variety, due to an insufficient supply of moisture to the fruit. Such specimens show a proportionally larger accumulation of tissues around the calyx end of the fruit as compared with the stem end. So, too, due to frost injury, Bartletts in particular frequently attain a form known as "bullnecks," showing a more or less abortive condition around the seed cavities but an extreme development of parts in close proximity to the stem. Quite often such malformed specimens constitute an appreciable fraction of the total crop. Naturally, exceptions of this kind will more or less interfere with a definite calculation of the increase in weight of the fruit as measured by enlargements of the transverse diameter. (See Oreg. Agric. Col. Exp. Sta. Bul. 162, pp. 16-17.)[3]

It is apparent from the foregoing considerations that a very appreciable daily or weekly addition in weight may be expected during the harvesting time. But in order safely to realize the largest possible tonnage one must measure quite accurately and at rather close intervals the exact stage of maturity of the fruit. This is especially essential where Bartletts are kept late on the trees, as for the canning trade. Under such circumstances the pressure test may be used as the most reliable guide in all harvesting and storage operations.

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation of the ready cooperation of owners and managers of the many fruit-growing and marketing concerns, who willingly assisted in this work. They are too numerous to be individually mentioned here. Special acknowledgement is due to Professor C. E. Thomas, who attended to the mechanical details in constructing the pressure apparatus.

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Oregon Agricultural College
Experiment Station

The Principal Stock-Poisoning Plants of Oregon

By

WILLIAM E. LAWRENCE

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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*On leave of absence.

Fig. 1. The result of eating poison larkspur.

POISONOUS PLANT CHART

The six most important stock-poisoning plants in Oregon, precautions, control, symptoms, and remedies.

	Larkspur	**Death camas**	**Water-hemlock**	**Lupines**	**Fern**	**Loco**
	SAVE THAT COW	WATCH YOUR SHEEP AND LAMBS	PROTECT ALL STOCK	WATCH YOUR SHEEP	FEED GOOD HAY TO HORSES	WATCH YOUR HORSES
	Western Oregon	All sections.	All swampy sections.	All sections.	Serious in Western Oregon only.	Serious in Eastern Oregon only.
SPRING	Keep off badly infested areas. Turn on the sheep. Allow them to eat down the larkspur.	Avoid infested areas. All parts of plants dangerous. Dig death camas up when in flower. Get the bulb.	Grows in swamps. Rootstock dangerous all year. Young shoots dangerous in spring.			
SUMMER		Cattle and horses may also become poisoned, but only rarely. Don't cut hay containing much "lobelia."	Eradicate the water hemlock by digging out the rootstocks, carrying them off the field and destroying.			Dig out by cutting below the crown before the plant is in flower.
FALL		Bulb poisonous at all times but not usually accessible in fall. Is your hay free from "lobelia"?	The tops are not dangerous in hay.	Avoid the lupine in pasture, on range, or when driving. The pods and seeds are most poisonous.	Fern causes staggers. Feed good, fern-free hay to horses.	Keep horses off infested areas when feed is short.
WINTER			Fence off the pile of roots which have been dug up. They do not lose their toxicity for years.	Is your hay free from poisonous lupines?	FEED GOOD HAY	Loco is a slow-acting poison. The loco habit may become started at any time.

SYMPTOMS	Repeated falling, accompanied with such weakness that for a variable period the animal is unable to rise. Staggering when up, spasmodic movements when down, constipation, nausea resulting in vomiting and death from respiratory paralysis.	Frothing at the mouth, vomiting, trembling, sometimes spasmodic struggles for breath, great weakness, the animal sometimes lying two or three days before death. Death from respiratory paralysis	Excessive frothing at the mouth, gnashing of teeth, pain, nausea, violent convulsions, and death.	Nervousness, weakness, partial paralysis, sleepiness, convulsions, death.	Unsteady gait. Appetite good. Nervousness.	Erratic movements, constipation, progressive emaciation. Effects are chronic, extending over a time varying from a few weeks to 2 or 3 years. Death ordinarily results from starvation, the animal ceasing to eat or drink.
REMEDY IF ANY	Keep the animal still, with head up hill. Give hypodermic injections of eserin.	Keep poisoned animals quiet. There is no satisfactory medical remedy.	For domestic animals, none. For man an emetic.	None for range animals.	Remove all ferny hay and ferny bedding.	Good food. Laxatives. Strychnine for cattle. Fowler's solution for horses.

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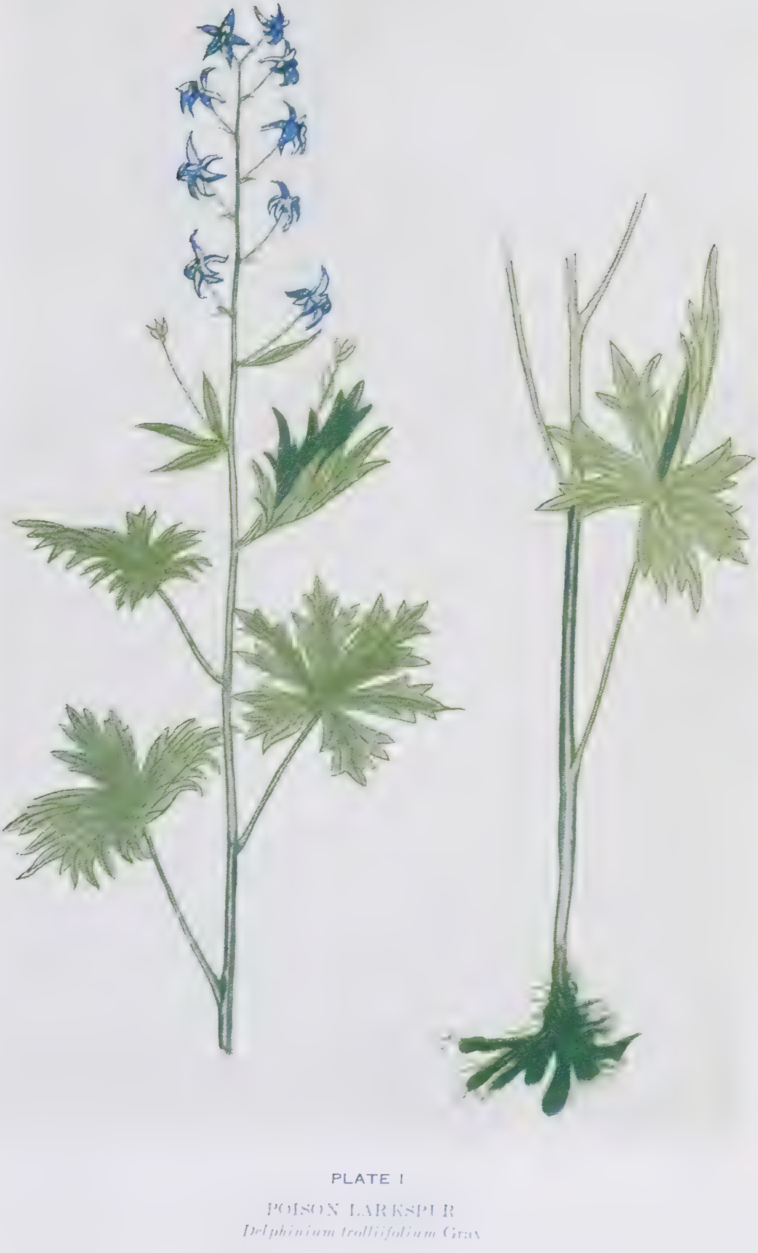

PLATE I

POISON LARKSPUR

Delphinium trolliifolium Gray

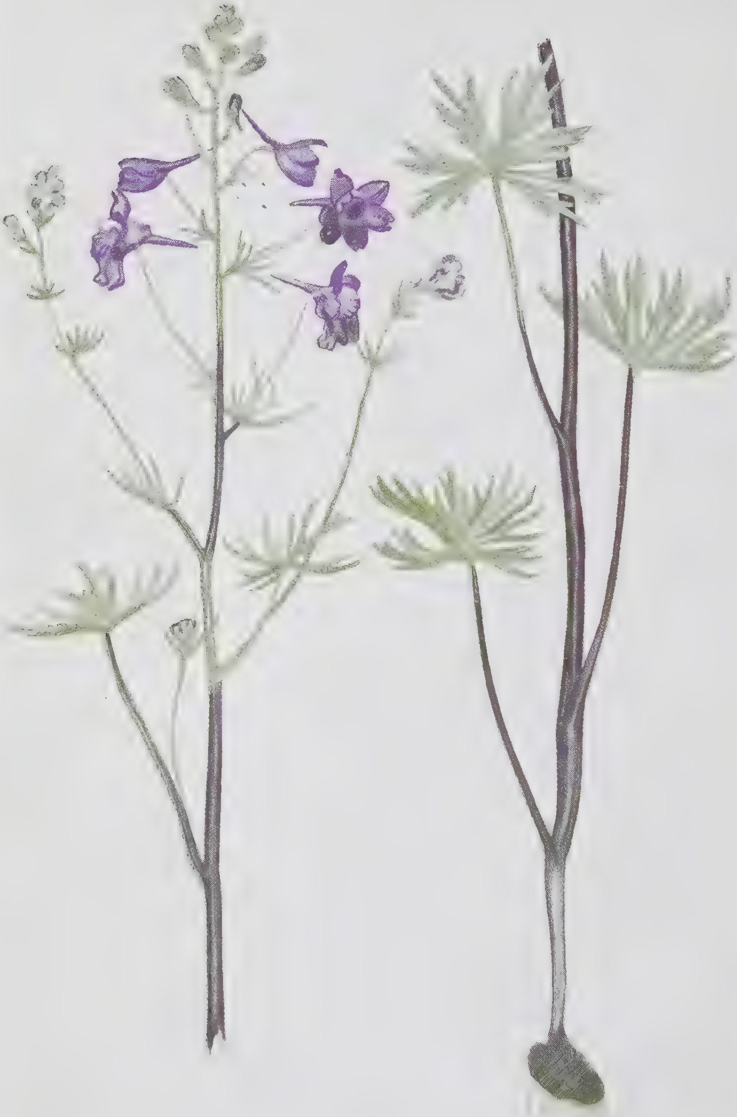

PLATE II

LOW LARKSPUR

(*Delphinium menziesii* D. C.)

The Principal Stock-Poisoning Plants of Oregon

By WILLIAM E. LAWRENCE

The purpose of this bulletin is to put into convenient and readily accessible form the information regarding poisonous plants that will be of most use to the Oregon farmer or stockman. The presentation is necessarily incomplete and many of the special cases known to the ranchman could not be treated here. The idea underlying the choice of material has been to aid the owner in working out his problems of stock management.

PLANT POISONING OF STOCK AND ITS PREVENTION

EXTENT OF POISONING IN OREGON

The annual toll of the poisonous plants in Oregon is surprisingly heavy, and with the increase in livestock values the seriousness of these plants becomes greater. On the open range the loss from poisonous plants is much greater than that from infectious and contagious diseases.[25] Losses from poisonous plants are also said to be much greater than those caused by predatory animals.[25] There are no accurate data which can be cited regarding actual annual total of losses. For the Western ranges it has been estimated by Marsh and others that larkspur frequently causes losses among individual herds of cattle up to 10 percent, death camas or lupine 50 or 60 percent, and loco from 5 to 50 percent. By far the greater number of losses are never reported.

Every stockman should know the leading poisonous plants, finding out where they grow and why they cause poisoning, then so manage the stock that they do not have access to dangerous plants. This is the underlying principle of a rational policy in stock management to avoid losses from poisonous plants. Cures must not be relied upon. They are too uncertain even if poisoned animals are discovered before death. Fully half of the deaths due to poisonous plants occur before the suffering animals are discovered by their owners. How to know the plant, how to recognize the conditions of danger, and how to prevent losses are the questions which this bulletin attempts to answer in a brief way.

CONDITIONS AFFECTING STOCK-POISONING

The condition of the poisonous plant, the condition of the animal, the season of the year, and abundance of feed are the big factors in the stock-poisoning problem. These factors vary so much in different localities and from year to year that the farmer should regard his own problems as demanding his own personal study. Some of the most important points to be kept in mind may be discussed here.

The Plant. It is not enough to know that a certain plant contains a violent poison. One must also consider whether plants are likely to be eaten in the pasture or on the range, or at the season of the year when dangerous, and whether the poison is contained in the part of the plant usually eaten. For example, larkspur is most dangerous before blossoming time; the poison in the water-hemlock is mostly in the rootstock.

The Animal. Young animals are more susceptible to poisoning than old ones, and animals new to a locality are more likely to eat poisonous plants than those familiar with the region. Sheep are thought to be immune to larkspur poisoning. Cattle are probably just as susceptible to death-camas poisoning as sheep, but because of their larger body-weight the cattle rarely get a sufficient amount to cause poisoning. Hungry sheep or a band driven hurriedly through lupine are more likely to eat a large amount of this conspicuous plant than if they were well fed, or allowed to drift slowly through and select their feed more carefully.

It has often been observed that when a large number of animals have been feeding under apparently the same conditions a few will escape poisoning. This may be due to the individual differences in animals regarding their susceptibility. On the other hand the feeding habits of some animals, especially sheep, are erratic. Sheep are known to eat plants on some days which they would not touch on others. This also applies to poisonous plants. Thus, when a few animals have become poisoned while others were not harmed, it may be safe to assume that only the few ate of the poisonous weeds.

Seasonal and Climatic Conditions. In the early spring larkspur and death camas are likely to cause more trouble than later because they often appear before good forage has had time to grow. Climatic conditions may cause one year an abundant fruitage of lupines and another year a sparse fruitage with corresponding effects on the amount of poisoning which occurs. In very dry years the good grass and other forage may become dried up while the lupines remain green and conspicuous, thus becoming a tempting morsel for stock.

Scarcity of Food. If the close relation between a scarcity of food and livestock poisoning were fully realized many of the losses could be avoided. Many poisonous plants are unpalatable, and it is a well-recognized fact that stock poisoning is materially less where there is a variety of other forage along with the poisonous plants. This is true even in regard to the loco before stock have acquired the habit of eating it. If good feed could be supplied during the poor range or pasture season very few animals would acquire the loco habit.[23]

The presence of good grass and forage in fields where poisonous plants are known to grow explains the absence of poisoning when it might otherwise be expected. It is known that larkspur, water-hemlock, wild cherry, and milkweed are all more likely to be eaten when there is little else to eat or where they form the conspicuous vegetation.

PREVENTION OF POISONING

Since scarcity of feed is by far the most important reason for the eating of poisonous plants by stock, every possible effort must be made to avoid the conditions which are likely to cause feed shortage such as over-grazing, over-stocking of the ranges, leaving stock on range after the good feed is eaten, using the same driveway or bedding-ground too often, or turning stock onto the range too early in the spring or when the snowfall has covered the grass. Special care must be observed during the dry seasons which yield a poor growth of forage. Cattle must be prevented from acquiring the common habit of feeding in certain sections of the range and depleting the forage there in spite of the presence of better pasturage on the same range at no great distance. The best rules to be observed in managing stock so as to minimize the danger of poisoning may be summarized as follows:

(1) Use the range when plants are least poisonous.

(2) Graze areas infested with poisonous plants with stock not affected by the plants.

(3) Supply additional feed if range is short. Handle stock quietly;[20] avoid excessive driving or rounding up with dogs. Avoid grazing in mass formation.

(4) Use a new sheep bedding-ground each night.

(5) Eliminate the fixed driveway, wherever practicable.

(6) Be especially careful of young animals or animals new to an area.

(7) Do not over-graze, either by over-stocking or by prolonged grazing.

(8) Rotate the grazing areas in different seasons.

(9) Inspect all your fields and pastures for the presence of poisonous plants.

(10) Eradicate poisonous plants or fence the areas.

(11) Feed hay free from fern or horsetail rush.

(12) Avoid use of hay from poison-sprayed cover crops.

Further emphasis should be given to the following[25] desirable practices. Many of the practices mentioned above have already been put into operation on the United States National Forests and have proved successful. They may also be practiced to advantage by the small farmer or rancher.

Use of the Range When Plants Are Least Poisonous. Reference to the accompanying poisonous plant chart will give the reader an idea of the season when each poisonous plant is most dangerous. The death camas dries up after blossoming and fruiting time, so that the danger period has passed by May or June. Low larkspurs are gone usually by July 1, but the tall larkspur may persist until late summer or fall. The lupines are most dangerous in late summer and fall when the pods are forming. No actual dates can be relied upon, however, because of the difference in climatic conditions from year to year. Local and altitudinal conditions also are so variable that an actual inspection of the range is the only safe guide.

Rotation of Kinds of Stock. Areas infested with one kind of poisonous plant need not be lost to pasture, because during the danger period stock that are not likely to become poisoned may be put upon the ranges.

Larkspur-infested areas may be grazed by sheep or horses through the larkspur-poisoning season; cattle and horses may be safely put in fields where death camas or lupine grows. This method is easier and more practicable than an attempt to alter the range. The kinds of plants found growing upon a range are presumably well suited to it so that the task of eradication is often difficult.

Using non-susceptible animals on an infested range tends to keep down the poisonous plants both because they may be eaten occasionally and because they may be tramped down. On the other hand, stock that avoid the poisonous plants will favor an increase in their abundance.

"Bedding Out" Method. If sheep are bedded on the same ground two or three nights in succession, all the good feed is eaten on the way to and from the bed ground and around it, while the dangerous plants remain to entice the unwary animal. The use of a new bedding-ground each night has been found much safer. This is advocated by the Forest Service and is called the "open herding," or "blanket herding," or "bedding out" method.

Driveways. What is true regarding bedding systems may also be applied to driveways. Fixed driveways should be eliminated whenever practicable because the first bands eat the good feed, leaving only the poisonous plants, if any are present, for succeeding bands. Most of the losses from wild cherry are said to occur under these conditions.[26] (Page 18.) Sometimes the driveways become almost bare of vegetation so that sheep become hungry and are ready to snatch at the first green thing they meet instead of choosing their feed. Both sheep and cattle should be allowed to drift along over new driveways, so that ample opportunity may be had for selection of good feed.

Common Use,[25] or Change in Class of Stock.[25] [20] The rotation of stock upon the range is not only of value in controlling the poisonous-plant problem, but it is also beneficial to the maintenance of the vegetation and results in a higher carrying capacity. Sheep, for instance, do not care especially for the grasses, preferring to eat weeds and other browse which cattle are likely to pass by. One type of stock may in this way follow another on the same range to good advantage. This practice of rotation grazing, however, must not be followed blindly, but should be guided by a careful study of the range from year to year.

Eradication of Poisonous Plants. If it does not prove practicable to handle the poisonous-plant problem in the ways suggested above, it may be found desirable to eradicate the plants. Eradication methods are discussed under the special treatment of each plant.

DIAGNOSIS

Diagnosis of the symptoms of poisoning is often rather uncertain. Ability to make a reliable diagnosis requires long experience and a thorough knowledge of the circumstances. For the more important poisonous plants an examination of the chart will give the best idea of the probable cause of poisoning in any particular case.

If the trouble is with cattle, either larkspur or water-hemlock is very likely to be the cause. If sheep are dying, death camas or lupines will be the probable cause. In horses the symptoms of fern staggers or loco poisoning are so well marked that diagnosis is seldom difficult. If the cause of poisoning is unknown to you, it is well to call a veterinarian in consultation.

REMEDIES

Remedies for livestock poisoning are often of rather uncertain benefit, and unless the proper methods are used more harm than good may be done. The best thing for stock poisoned on larkspur or death camas is to keep them quiet. The excitement caused by giving medicines is often sufficient to cause death from poisoning before the remedy can take effect. Unless you are very sure of your diagnosis and remedy, it is always best to summon a veterinarian. A brief summary of the symptoms and known remedies will be found in the chart and also under the special discussion regarding each plant.

THE PRINCIPAL POISONOUS PLANTS

POISON LARKSPUR

Delphinium menziesii D. C.
Delphinium trolliifolium Gray
Delphinium bicolor Nutt.
Delphinium glaucum Wats.
Delphinium scopulorum Gray
Delphinium simplex Dougl.
Other species of minor importance

It is dangerous to allow cattle to graze in a field or on a range where larkspurs are common in the spring of the year. Larkspurs are so definitely associated with cattle poisoning and the plants so easily recognized when they flower that every cattleman should become acquainted with them and with the conditions associated with larkspur poisoning.

Common Name. The common name, larkspur, is so generally known that few other common names are applied to the plant. It is, however, occasionally referred to as "poison," "poison weed," and "cow poison."

Kinds of Larkspur. Several species of larkspur are found in the State. Those responsible for most of the cattle poisoning are listed above. There are two main classes of larkspurs: tall larkspurs and low larkspurs. The poison larkspur *(Delphinium trolliifolium* Gray*)* which is responsible for most of the losses in Western Oregon is a tall larkspur, while the low larkspur responsible for most of the cattle poisoning in the eastern part of the State is *Delphinium menziesii* D. C. Both tall and low larkspurs are found in all sections of Oregon. As will be pointed out later, this is a convenient method of distinguishing between the different kinds of larkspur when the question of control is to be considered.

Animals Affected. Most larkspur poisoning occurs among cattle. Horses, although susceptible, are seldom poisoned under range conditions. Sheep are scarcely if at all susceptible, and they may eat from two to five times as much as cattle without any harmful results. In fact, it is recommended that sheep be first grazed upon larkspur areas in order that the areas may become safe for cattle.

Extent and Conditions of Poisoning. It has been estimated that from three to seven percent of poisoning of cattle in the United States is due to the larkspur, which is greater than that due to any other plant except loco. Because of the common occurrence of larkspur in the cattle sections of Oregon, a higher percentage of losses in this State are due to larkspur than to other poisonous plants. As cattle are not usually herded the extent of losses is not exactly known, but the aggregate of one-by-one losses in many herds is very heavy.

Larkspur poisoning is not equally troublesome in all localities where the plant occurs. The danger is worse where good feed is scarce and where because of natural conditions the larkspur forms a very conspicuous part of the vegetation. Where there is plenty of good feed the stock will rarely touch the poisonous plant except when abnormally hungry.

When cattle are driven over larkspur areas some of the herd may become poisoned while others may not. One reason for this lies in the condition of the individual animal, which is a most important factor in stock poisoning. Some animals are rather resistant to the effects of poison, while others may be in a highly susceptible condition. When hungry the cattle are less careful in the selection of food than when well fed and are likely to eat of the larkspur when they would ordinarily leave it alone. Stock should, therefore, never be driven over larkspur areas when hungry, although when not excessively hungry, as for example in the afternoon, they may be admitted with reasonable safety to fields where the larkspur is growing in not too great abundance.

Poisonous Parts of Plant and Quantity Required to Produce Poisoning. The amount of larkspur necessary to cause death varies. Experiments by the United States Department of Agriculture[30] show that poisoning may occur when as little as 30 pounds per 1000 pounds weight of animal is eaten. Or, in other cases, it may require as much as 84 to 280 pounds per 1000 pounds weight. It is dangerous for the animal to eat more than 3 percent of the total body weight in one day, although from three to four times this much may be eaten if the feeding period is prolonged.

Although it is a common belief among stockmen that the roots are the poisonous parts and that poisoning is more likely to occur after a rain because it may be possible to pull the roots from the ground at that time; yet feeding experiments[30] thus far have failed to substantiate the belief that the roots are violently toxic, while they have shown that the parts above ground, especially the leaf, are responsible for stock poisoning. The stem is very brittle, and although it is possible for some larkspurs to be pulled up by the root, it is improbable that cattle will get any considerable number of the roots to cause poisoning.[30] The seeds are known to contain more of the poison than other parts of the plant. The seeds, however, are less likely to be eaten in the field and are probably not so important as the foliage.

When is Larkspur Poisonous? The low larkspurs are poisonous throughout their life, but since the leaves die down soon after the blossoming period the plants seldom cause poisoning because the cattle do not touch them after this time. Although the tall larkspurs are most poisonous when young, and become less poisonous as the season progresses they are still dangerous during and after blossoming time.[2] Both tall and low larkspurs are, however, to be regarded as dangerous until after blossoming time. They are less dangerous after blooming and it is usually safe to turn cattle on the larkspur-infested areas after the plants have bloomed.

Where Do the Larkspurs Grow? The low larkspur is found usually on the open hillside ranges and pastures in both Eastern and Western

Oregon at both low and high elevations. The plants grow scatteringly, which very much lessens the danger of poisoning from the low species.

The tall species of larkspur more often grow under the shade, or partial shade, in the damper situations, in the more timbered areas of the State, or along the streams. They are common in the gulches and mountain valleys and on the bottom lands in all parts of the State. In favorable spots the tall larkspurs are apt to grow thickly, and cattle feeding in such areas are much more likely to become poisoned than where the growth is sparse.

How Can the Larkspur Be Recognized? Larkspurs usually have violet blue or purple flowers, sometimes creamy white. Each flower produces a long spur, like a cock's spur, of which the name is a reminder. (Plate II.) The seed pods occur three in a place. They are like those of a columbine, but fewer. The leaves of the tall larkspur in their early stages may be confused with those of the harmless wild geranium which often grows in similar situations, but the flowers are entirely different.

Veterinarians and others familiar with the microscopic structure of the stem of larkspurs may upon careful examination determine the presence or absence of larkspur stems in the contents of the stomach.

Preventive Measures. Efficient protection against losses from the larkspur depends upon the ability of the stockman to recognize the larkspur and to locate the infested areas. Cattle must be kept away from such dangerous places, especially when first turned onto the range after a winter on dry feed or when in poor condition. This may be done by herding away from infested areas—"riding for poison"—as is done in some parts of Oregon. After the first of July, however, larkspur-infested areas are usually safe for cattle, except in the high mountain ranges.

It has sometimes been found practicable in the more densely infested areas in Oregon to eradicate the tall larkspur by grubbing. The saving from the prevention of cattle losses in one season will often more than pay for the cost of digging out the larkspur, and if this is carefully done the first year the cost for succeeding years will be much less. Digging up low larkspurs is not ordinarily practicable because of their usually scattered distribution.

Salt should be placed on ground free from and remote from larkspurs, and the salting ground changed occasionally so that the range may not become overgrazed.

Directions for Digging Tall Larkspur.[*] The roots should be dug out six to eight inches below the surface of the ground as soon as the plants have made sufficient growth to be readily recognized. Roots dug out should be shaken free of soil and piled in the sun; after they have dried sufficiently they should be burned.* Piling them in a heap increases the cost and has been found to be unsatisfactory, unless they are finally destroyed.

Grazing Off Larkspur with Sheep. It is well known that areas affected with larkspur can be safely grazed off by sheep before cattle are turned onto the field. Sheep should be closely herded, the herder making certain that all the larkspur is eaten or tramped to the ground. Otherwise, the sheep may pass by the larkspur and feed upon the valuable forage only; the larkspur thus left exposed more conspicuously than before would result in greater subsequent cattle losses than if no sheep had been turned upon the range. Of all the methods of preventing larkspur poisoning, fencing is perhaps the least desirable because of the cost of fencing, the expense of maintaining the fences, and the resulting loss of forage. Under certain circumstances, however, this method has its use. In the long run the most satisfactory method with the tall larkspur, as shown by the investigations of the United States Forest Service, is that of eradication by digging, for when the plants have been grubbed out of the spots where they grow abundantly there is very little danger from the sparsely scattered plants on the rest of the range.

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*Unpublished data supplied by Director James T. Jardine.

Symptoms of Poisoning. Doctors C. Dwight Marsh, A. B. Clawson, and Hadleigh Marsh of the United States Department of Agriculture give the symptoms and remedy as follows:

"Repeated falling, accompanied with much weakness, the animal unable to rise, staggering when up, spasmodic movements when down, constipation, nausea, resulting in vomiting and death from respiratory paralysis."[24]

Remedy. Doctors Marsh, Clawson, and Marsh[32] further state:

"Cattle poisoned by larkspur should be kept as quiet as possible and turned with heads uphill; they should be paunched if bloating occurs; should not be bled; and in most cases may be saved by a subcutaneous injection of 20 cubic centimeters (6 drams) of eserine.

"Physostigmin salicylate	1 grain
Pilocarpin hydrochlorid	2 grains
Strychnine sulphate	½ grain"

DEATH CAMAS

Zygadenus venenosus Wats.
Zygadenus paniculatus Wats.
Other species of minor importance

The death camas is perhaps not so well known as a poisonous plant as any other of the six important poisonous plants of the State. Practically all losses of sheep due to the death camas could be avoided if the poisonous nature of this plant was more generally recognized.

Common Name. This plant is perhaps best known as death camas. There are about ten common names applied to it in different sections of the country, of which "lobelia," poison camas, alkali grass, poison grass, wild onion, and poison sego may be mentioned. Although known so commonly in the Northwest as "lobelia," it is not a true lobelia. It has also been called "hog potato" because hogs are said to thrive upon it.

Kinds of Death Camas. There are two species of death camas found commonly in Oregon. The meadow death camas, *Zygadenus venenosus*, is widely distributed, being found in both the eastern and western sections. The foot-hill death camas, *Zygadenus paniculatus*, is a larger and more branched form. It is found chiefly in the sage-brush region.

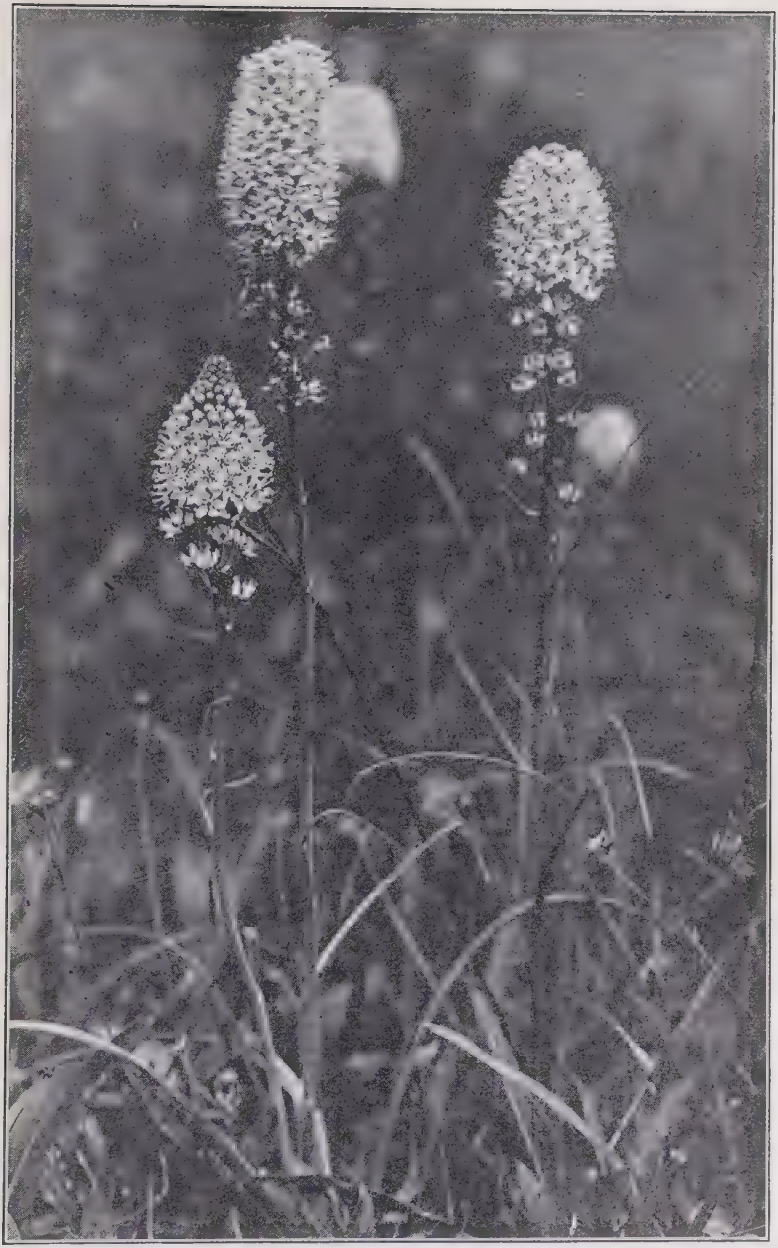

Fig. 2. Death Camas. (*Zygadenus venosus* Wats.) showing the flower clusters in the spring.

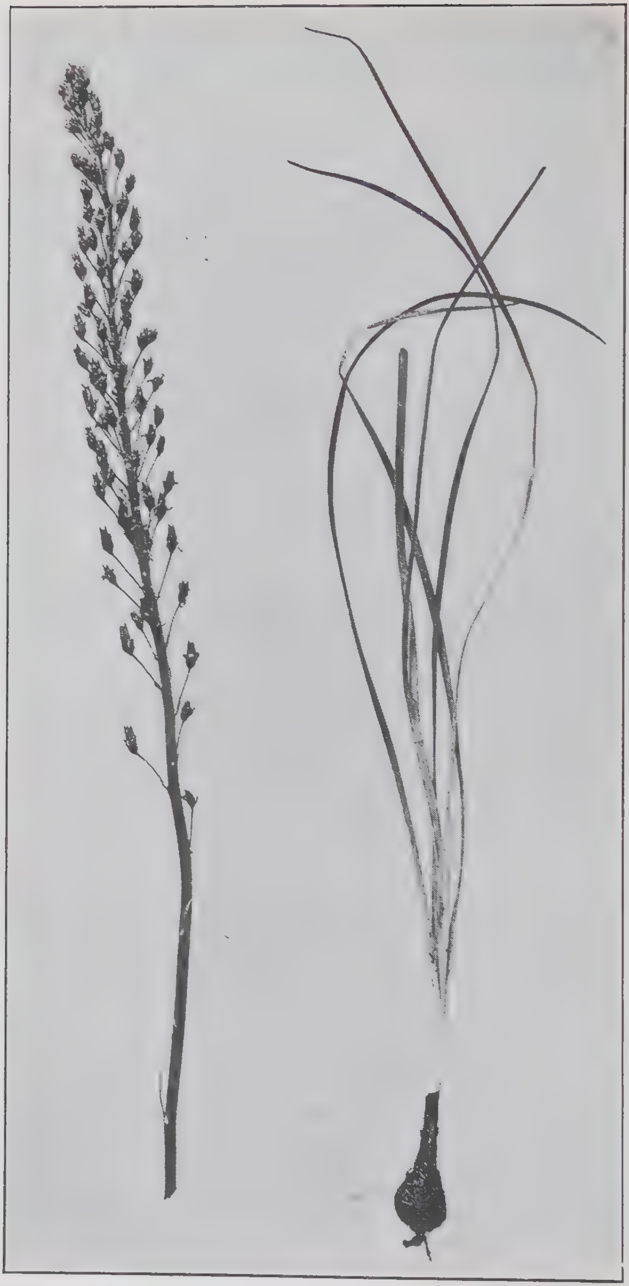

Fig. 3. Death Camas. (a) Fruits. (b) Bulb, leaves, and portion of the stem.

Animals Affected. Although horses and cattle may occasionally become poisoned by eating the death camas, by far the greater number of losses occur among sheep. Horses are sometimes made sick but are apt to recover soon. Death-camas poisoning in cattle is not common, although deaths have been reported. The bulb of this plant is poisonous to man. Children sometimes dig up the bulbs mistaking it for the edible camas. The method of distinguishing these two plants will be given below.

The Extent of Poisoning. The heavy losses among sheep are due to the method of herding and to the fact that it takes but little of the plant to poison sheep because of their small size. If death camas is present sheep are apt to eat more of it when they are kept close together than when allowed to scatter out. Few sheep herders are acquainted with the plant or its poisonous qualities. Deaths among sheep frequently ascribed to other plants, such as the lupine, are often due to the death camas. Losses from death camas sometimes run up to 21 percent in a band.

The Poisonous Parts of the Plant and Quantity Required to Produce Poisoning. Experimental tests show that the parts of the death camas are poisonous in the following order beginning with the most toxic: seeds, mature pods, flowers, leaves, bulbs, roots, young pods. The United States Department of Agriculture[29] has demonstrated that the flowers, leaves, and bulbs are dangerous to sheep when one-half pound per hundred-weight has been eaten within a short space of time. Smaller doses on the range may prove fatal.[8] The seeds are about four times more poisonous than any other part of the plant; however, under range conditions the seeds and bulbs are of little importance.[8] Lambs are probably more susceptible to the poisoning than old sheep. Recent experiments[7] indicate that lambs are not poisoned from the ewe's milk. Cattle and horses are probably as susceptible to the poison as sheep, but they almost never get enough of the plant to cause trouble. Hogs are not affected.

When is Death Camas Poisonous? The plant is poisonous throughout its entire life and the bulbs are poisonous in all seasons of the year, but from the standpoint of stock poisoning the danger period comes in the spring before the tops dry up. This is largely due to the scarcity of food early in the season. Most of the losses occur in May and June.

Where Does Death Camas Grow? Death camas requires a moist but not a wet or marshy place to grow. Wherever moist conditions occur in the early part of the year one may expect to find death camas growing whether in the mountains or in the lowlands. It is usually found in the open or partly sunny meadows, on moist hillsides, or on the lowlands of both Eastern and Western Oregon. The larger species, the foot-hill death camas, mentioned in a preceding paragraph is found in the sage-brush or juniper sage-brush desert. Sheep losses due to these plants have been reported from Western Oregon, the Blue Mountain section, and the mountains in the southern part of the State.

How Can Death Camas be Recognized? Death camas can be easily recognized in the latter part of the spring when the plant is in flower.

At this time dense heads of small greenish-yellow or whitish-colored flowers are sent up on a shoot from six to twenty-four inches high. Plants having this description should be examined further to see if they possess grass-like leaves that come from an onion-like bulb beneath the ground. The leaf of the death camas, however, does not have a sheath-like part surrounding a jointed stem as in the grasses. The bulb of death camas is small, resembling an onion or the edible camas; however, it does not have an onion-like odor. If this bulb is dug out of the ground carefully, it will be observed that the outer layers of the bulb are brownish or black in color. Areas infested with death camas may be easily recognized during the flowering season.

The bulbs of the death camas and the edible camas are easily mistaken, and results disastrous to human life sometimes occur because of the confusion. The flower of the edible camas is rich blue, and much larger than that of the death camas. The leaves are also longer, wider, and a deeper green than the leaves of the poisonous plant.

Preventive Measures. The most important thing is to keep sheep away from death camas. This can not be done unless it is possible for the sheep owner or herder to recognize the plant. This is easiest at the time the plant is in flower, but with practice the plant may be recognized either before or after blossoming time. It should be remembered that it is just as poisonous at one season of the year as another. After the plant has been recognized and the patches located care should be taken to keep sheep away.

Sheep should be fed well before going upon a drive through infested regions, because hungry sheep are apt to eat with less care and may consume large quantities of the death camas in a comparatively short time. Sheep should be salted daily to prevent the development of a depraved appetite that would result in their eating poisonous plants.

The bitter substance contained within the death camas is very distasteful to both sheep and cattle. It is only when cattle are thin and hungry that they will bite off the death camas, and apparently only when they are driven hard will death result.

Sheep when grazing quietly will avoid the death camas, but will eat anything when being trailed or hurried from one place to another.

In the spring before blossoming time the plant is especially dangerous, not because it is any more poisonous but because conditions of other forage are apt to be less favorable and the sheep are tempted to eat more of the death camas than later on.

Symptoms of Poisoning. "The symptoms are usually frothing at the mouth accompanied by vomiting and trembling. There are sometimes spasmodic struggles for breath, the animals manifesting great weakness. They sometimes lie two or three days before death. Death comes from respiratory paralysis."[24]

Remedy. "Animals poisoned with the death camas should be kept quiet, and they may recover. There is no satisfactory medical remedy." (Marsh, Clawson, and Marsh.)[29]

WATER-HEMLOCK

Cicuta vagans Greene
Cicuta occidentalis Greene
Cicuta douglasii (D. C.) C. & R.

The Oregon water-hemlock is the most violently poisonous plant within the State, although it is not the most important from an economic standpoint. All stockmen who pasture livestock on swampy lands or along swampy streams and ditches should become acquainted with the water-hemlock and its poisonous nature.

Common Name. There are four different kinds of water-hemlock within the State; namely, the Oregon water-hemlock, Douglas water-hemlock, Western water-hemlock, and bulbous water-hemlock. Since more than one of these water-hemlocks seldom occur in the same locality, they may all be referred to as water-hemlock, or cicuta. They are often erroneously called parsnips or wild parsnips. There are other plants called wild parsnips. Other common names applied to the water-hemlock are "poison parsnip," "cowbane," "water parsnips," "death-of-man," "children's bane."

Animals Affected. The rootstock of this plant is poisonous to all animals including man. Most of the livestock losses occur among cattle, although instances of horse and sheep poisoning are known. Little is known regarding the effect on goats of eating hemlock, but it has been stated that swine are not poisoned by it. Cases of poisoning in man, and particularly in children, have been known in former times, but this plant is becoming so well known as a poisonous weed that it is carefully avoided and nowadays few, if any, cases are reported.

Extent of Poisoning. Livestock losses due to the water-hemlock were more prevalent in earlier days than at present, although frequent losses are reported here and there over the State. An estimate in 1903 placed the animal losses from the water-hemlock at 100 cattle in Oregon. In 1919 one stock company alone lost as many as 100 cattle. The losses continue year after year, but may be reduced if the necessary precautions are taken to prevent poisoning. The losses are reported in all sections of the State. Individual owners sometimes lose heavily, but the total number of deaths do not compare with the losses due to larkspur.

The Quantity Required to Poison and the Parts of the Plant that are Poisonous. The small number of losses due to this plant is no doubt due to the fact that the rootstocks are the most poisonous parts. In the summer or autumn the tops may be eaten by livestock in the fields or in the hay with little danger of harmful effects. On the other hand, the first leaves and stems that appear in the spring are almost as dangerous as the rootstocks.[8] At any time of the year it requires only a very small quantity of the rootstock to produce poisoning sufficient to cause death. The poisonous substance exudes in small yellow droplets from the cut surface of the rootstock.

Experiments conducted at the Oregon Agricultural College Experiment Station (1897) showed that a portion of the rootstock about the size of a walnut was sufficient to kill a cow. The plant used was the Oregon water-hemlock. Recent experiments in Nevada[8] on the Western water-hemlock show that a somewhat larger amount is necessary. Both

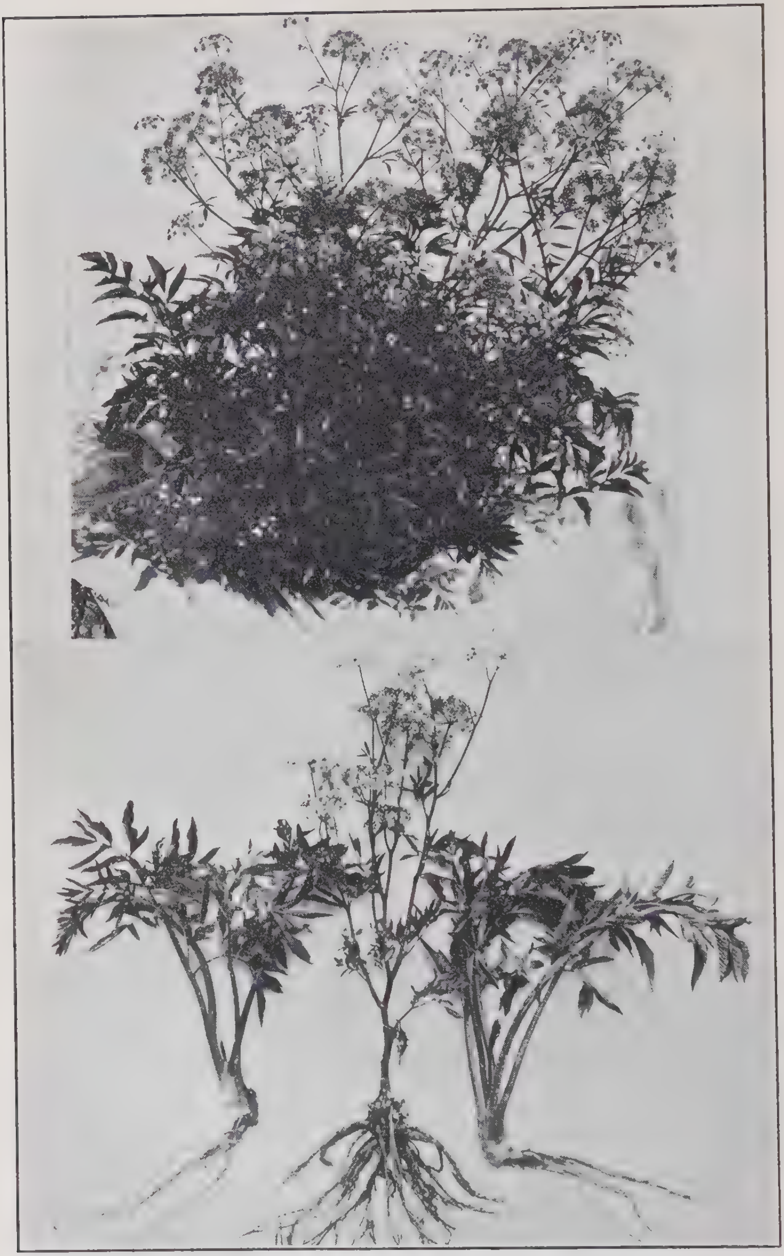

Fig. 4. Water-hemlock (*Cicuta vagans* Greene). (a) Plant in flower and fruit. (b) Showing off-shoots separated from the parent plant, which is in flower.

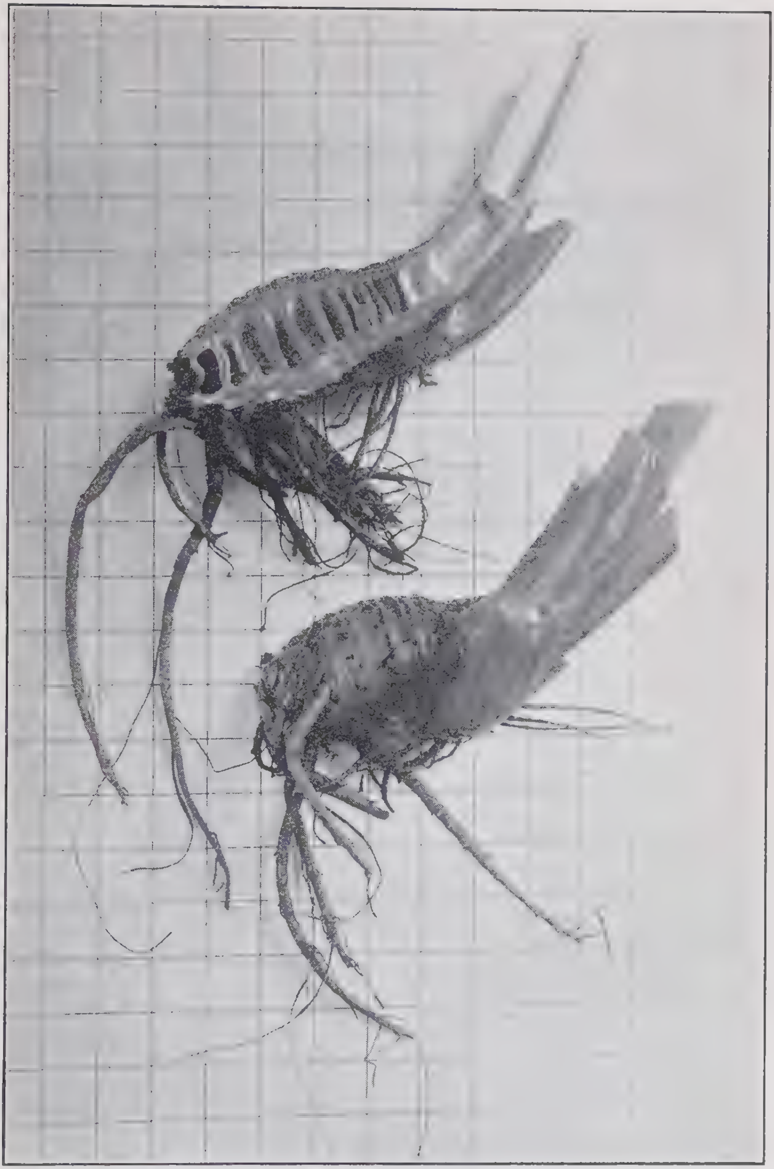

Fig. 5. Underground portion of the stem, the most poisonous part of water-hemlock. Upper view shows the characteristic partitions.

of these tests indicate the violent nature of the chemical substance found in the rootstocks.

When is Water-hemlock Poisonous? The rootstocks of the water-hemlock are almost equally poisonous in all seasons of the year, except perhaps during the growing season when the amount of poison contained within the rootstocks may be somewhat reduced. The early spring when the young shoots are still poisonous, is the most dangerous time.[8]

Water-hemlock Grows in Swamps. All four kinds of water-hemlock mentioned above grow in swampy places. In general the Oregon water-hemlock is common in the swamps of Southern and Eastern Oregon and in marshy places along the seashore. The Western water-hemlock is found in the Blue Mountain region and the Douglas water-hemlock in Western Oregon. The Oregon water-hemlock is also found in Western Oregon but not developed to as great an extent as in the swamps in the eastern part of the State. The water-hemlock occasionally grows along irrigating ditches and open drainage ditches.

How Can the Water-hemlock be Recognized? The water-hemlock or cowbane belongs to the parsnip family, producing a parsnip-like cluster of flowers and fruits. The stem is jointed, smooth, and hollow. It stands erect and bears rather large leaves, two to three times divided, on stems from three to six feet high. The different kinds of water-hemlock may be known by their different rootstocks (really shortened and thickened stems). Note the shape of the rootstocks and the size of chambers and partitions in Fig. 5. The water-hemlock may be distinguished from the wild parsnip by the smaller and narrower leaf of the water-hemlock. The flower cluster is much larger and more conspicuous.

Other members of the parsnip family appear to cause livestock poisoning, but the exact nature of their poisonous characteristics is not well known. All cases of poisoning which come to the attention of stockmen should be referred to the Oregon Agricultural College Experiment Station, together with a specimen of the plant supposed to cause injury.

Preventive Measures. The safest policy is to dig out the water-hemlock by the roots or to fence the affected areas. If fencing shuts off a certain amount of good feed, however, there is always a danger of stock breaking through the fence. It is found to be a paying proposition in Klamath county, where the water-hemlock grows to an abundant extent, to dig out the rootstocks every year. Digging out the rootstocks should be done carefully. It is not necessary to remove the whole root system but to cut off and remove the thickened rootstock. It is usually customary to carry the rootstocks off the field and pile them in a heap. The rootstocks should not be left on the field because they are poisonous and may take root again if conditions are right. A pile of rootstocks should be carefully guarded or fenced because the dry rootstocks are known to cause poisoning after from one to three years. The best plan is to burn the rootstocks in a hole and then fill up the hole.

Symptoms of Poisoning. "The symptoms of poisoning of water-hemlock are very definite and may be characterized as excessive frothing at the mouth, a gnashing of the teeth, pain, nausea, violent convulsions, and finally death."[24]

Remedy. "There is no satisfactory remedy for domestic animals. For man, an emetic is given."[24]

LUPINES

Lupinus macrostachys Rydb.
Other species of minor importance.

When sheep die of lupine poisoning, death follows a very brief sickness. It is therefore doubly important that sheepmen become acquainted with the poisonous nature of the lupines and the conditions leading up to the poisoning.

Common Name. Although there are many different kinds of lupines within the State, they are all known by the one name. A few of the more conspicuous lupines are sometimes called sun-dial, old maid's bonnet, quaker's bonnet, Indian bean, wild bean, blue pea, blue bean. It is incorrect to refer to them as loco because this name is applied to an altogether different poisonous plant. Some lupines are valuable as forage and hay, if caution is observed in avoiding poisoning.

Animals Affected. Most losses from lupines occur among sheep, but horses, cattle, goats and swine may become poisoned. Experimental tests seem to indicate that almost all animals will be poisoned if they secure a sufficient amount of the poisonous part. But from a practical standpoint the poisonous character of lupines should be considered of real importance only in sheep ranching.

The Extent of Poisoning. The conditions underlying the poisoning of sheep from lupines seem to be various. Poisoning is rather spasmodic and not confined to any one time of the year or locality. Losses among sheep are very general, losses of several hundred being not at all uncommon and occasionally amounting to 50 percent of the band. Lupine is probably next to death camas in responsibility for sheep losses.

Quantity Required to Poison, and the Parts of the Plant Which are Poisonous. Experiments conducted by the United States Department of Agriculture,[31] seem to indicate that the parts of the plant are poisonous in the following order: seeds, requiring about one-half pound to cause poisoning; fruits, containing seeds, one and one-half pounds; pods alone, three and four-tenths pounds; leaves, probably poisonous, but the conditions and amount necessary to cause poisoning are not clearly understood. The green fruits of the silvery lupine *(Lupinus argenteus* Pursh*)* were found to contain the most poison, with slightly smaller amounts found in the ripe and green seeds.[3]

When are Lupines Poisonous? It will appear from the preceding paragraph that lupines may cause poisoning any time after the appearance of green pods.[3]

Conditions on the Range Under Which Poisoning May Occur. Sheep kept well fed on range that contains plenty of good pasture are not likely to eat a sufficient quantity of lupines, even though present, to cause poisoning. If it is necessary to drive sheep over an area containing lupines, it is desirable to allow them to drift slowly, giving them ample time to pick out the good forage from among the lupines. If sheep are

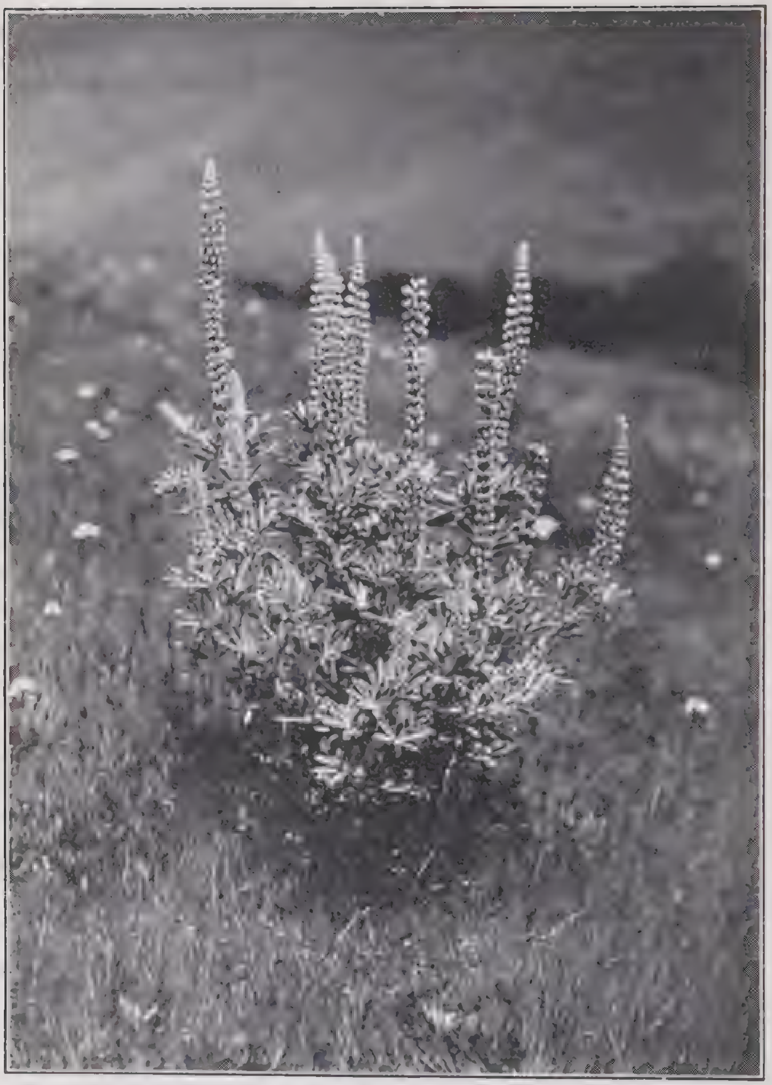

Fig. 6. Lupine (*Lupinus macrostachys* Rydb.)—a vigorous plant in the field.

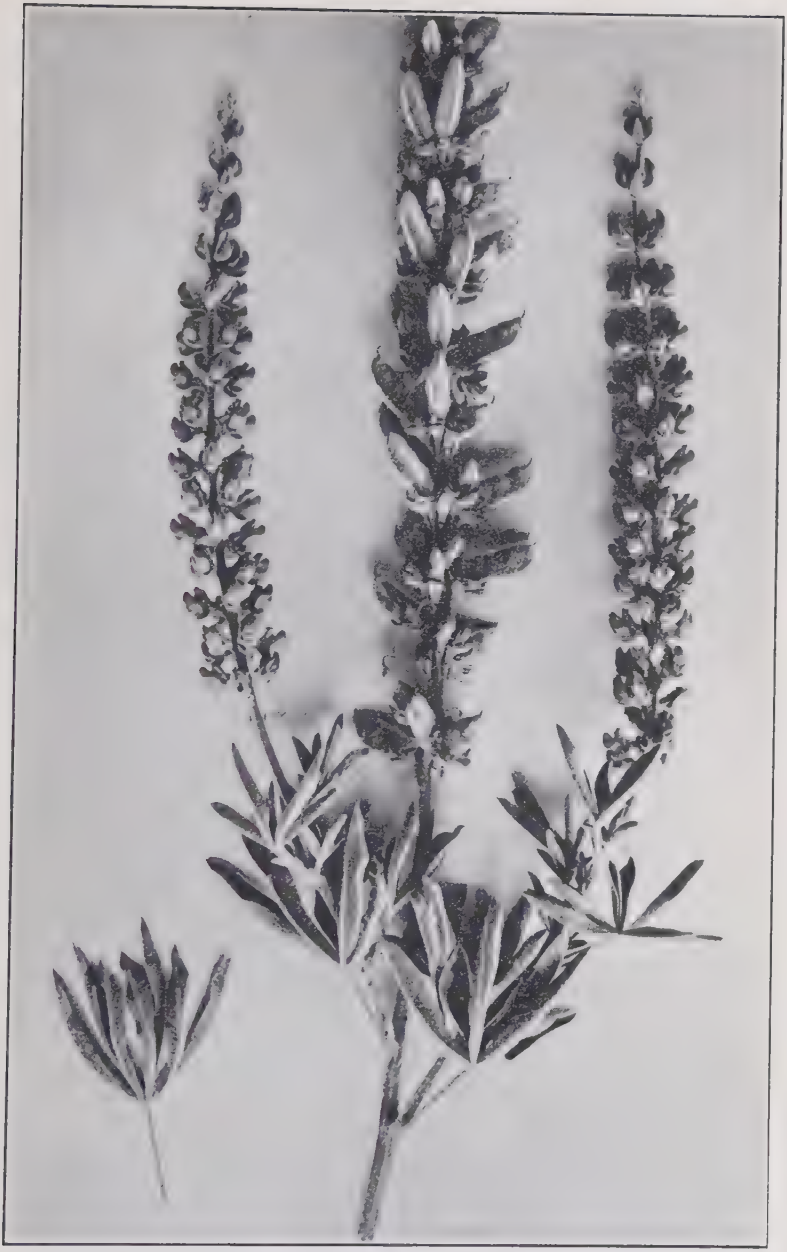

Fig. 7. Lupine (*Lupinus macrostachys* Rydb.), showing flowers and fruit.

hurried over the area they will in their eagerness for food snatch off the pods of lupines or the leaves, and eat a much larger amount of the poisonous plants than they would otherwise. Sheep that have become hungry on account of a lack of sufficient food during shipment or because of being hurried over long drives are more likely to eat the lupines and become poisoned than if they had been well fed. Sheep new to any locality are also more inclined to eat the poisonous plants. In the fall when the sheep are coming from the summer range, snowfalls may occur covering up the good grass and forage, thus exposing the taller lupines to the passing sheep. Under these conditions lupines would be eaten, whereas if plenty of good feed had been available these sheep would avoid all poisonous plants.

Where Do Lupines Grow? There are many kinds of lupines, and they are found in all parts of the State and under all possible circumstances, from moist to very dry and even desert conditions. It is known that some lupines are harmless while others are poisonous. But since it is difficult for the average person to distinguish the different kinds all should be looked on with suspicion when in pod. Some of the larger and definitely known poisonous lupines grow on plains. They usually grow in the deeper soil on the lower southern slopes or on the north-facing slope, where there is more moisture. They frequently occur under the shade of a forest and in all cases become luxuriant only when a sufficient amount of moisture is obtainable either by protection from forest shade or on deep soil.

How Can Lupines be Recognized? There is no poisonous plant which can be recognized with greater ease than the lupine. The form of the leaf is a reliable indication, and reference to the accompanying photograph will show that the divisions of the leaf all radiate from a common center, this fact suggesting the common name, sun-dial, which is applied to some lupines. The flower and pod are similar to those of the pea.

Preventive Measures. The conditions favoring poisoning have been pointed out, and it is obvious that if these are avoided much of the difficulty may be overcome. Proper management of sheep bands will be sufficient to avoid poisoning from lupines, which are too general in their distribution and too often associated with valuable forage to permit either eradication or the avoidance of most lupine areas. It is cheaper to buy hay and feed sheep, when being shipped from one point to another, than to risk losses from lupines following a period of hunger. Areas where poisonous lupines grow very abundantly should be avoided. One should learn to recognize the lupines and be especially cautious after snowfall or while driving through pastures of lupines. It should always be remembered that the pods and seeds are more poisonous than the rest of the plants and that more fruit is produced in wet seasons than in dry.

Symptoms of Poisoning. It is very important to remember in connection with the lupines that there are no preliminary symptoms of poisoning until the poisonous limit is reached. The amount necessary to cause the first symptoms of poisoning is so close to the amount which will cause death that it is difficult to find any symptoms that may be of value in applying remedies. This is due to the fact that the poisonous principle is excreted by the kidneys and that the effects of the toxic substances are not accumulated in the body. Animals may eat an amount just under the toxic limit one day and repeat the performance the next without any harmful results. If the amount of lupines eaten passes beyond the toxic limit, however, death is most likely to occur. This constitutes the reason for so large a percentage of deaths within the band. When any symptoms are manifest before death, they are nervousness, weakness, partial paralysis, sleepiness, convulsions, and finally death.[2]

Remedy. Recommendations based upon the work of the United States Department of Agriculture[3] are as follows: Exercise care in handling the flock, it being all important to avoid poisoning, because there is no satisfactory remedy that can be applied upon the range.

LOCO

Astragalus lentiginosus Dougl.

Loco poisoning is a problem of the dry country where juniper or sage-brush abounds. Many locos about which little is known also grow on the bunch-grass prairie and in the mountains.

Common Names. Many plants have been wrongly called loco weeds. and there are also many different kinds of true locos. The only names applied are loco weed or rattle weed. The purple loco or woolly loco and the white loco or rattle weed of the Rocky Mountains and Plains sections of the United States are not found in Oregon.

Animals Affected. Horses, cattle, and sheep are known to have been poisoned by the loco plants in other states, but so far as Oregon is concerned no records are at hand except of loco poisoning among horses. It is not at all improbable, however, that cattle or sheep may also have been poisoned on loco in this State. Further evidence on this point is needed and will be greatly appreciated if sent to the Oregon Agricultural College Experiment Station.

Extent of Poisoning. Loco poisoning occurs from Central Oregon eastward throughout the desert and semi-desert sections. The number of animals poisoned varies in different years, depending upon the abundance of loco plants. On the other hand, the prevalence of loco will not accurately indicate the amount of poisoning, because animals after they have once acquired the taste for the loco develop the habit of eating it in preference to other plants even when not particularly abundant.

Quantity Required to Poison and Conditions Affecting Poisoning. Like other poisonous plants locos are not at first eaten in preference to other vegetation. Some of them in fact are quite distasteful or unpalatable. When other good feed is scarce, as often happens on the juniper sage-brush ranges, stock are forced to eat every bit of green material they can find. When the loco is about the only green plant at certain seasons of the year it is not to be wondered at that horses in these sections acquire a taste for it. Loco is a slow-acting poison, the symptoms not appearing in horses until after they have acquired the habit of eating the plant. This condition makes it necessary to employ a method of stock management that will prevent an acquisition of this

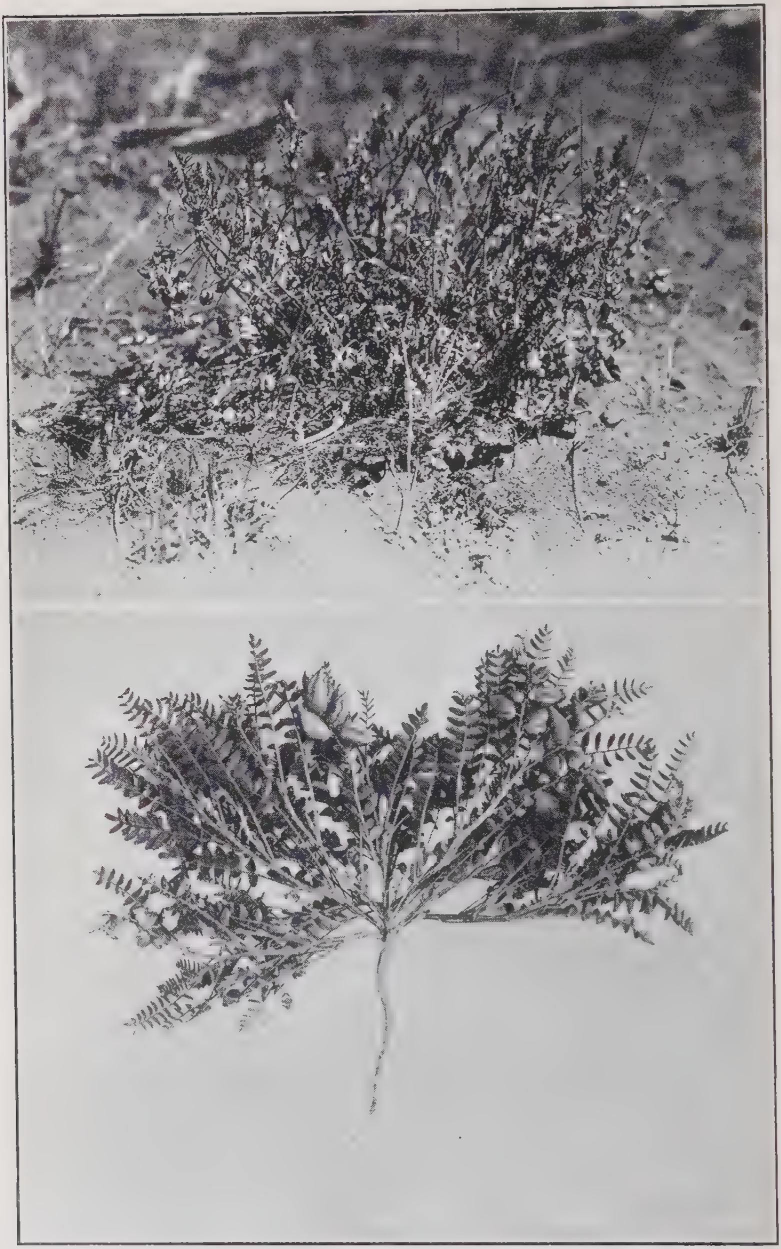

Fig. 8. Loco (*Astragalus lentiginosus* Dougl.) (a) A loco plant in the field. (b) Entire plant, showing the inflated pods.

habit, as it is almost impossible to break stock of eating locos or cure them of the disease after the habit has once been acquired.

When is Loco Poisonous? It is thought by some that the loco in Oregon is poisonous throughout the entire year, while others believe it to be harmful only between August and spring. The latter belief is probably based upon the fact that most of the losses occur from August to the latter part of winter or early spring. Horses will eat loco either green or dry, and it is probable that they acquire the habit of eating it while it is green and continue during the dry season when there is very little else to eat, until they have accumulated a sufficient amount of the poison to produce loco symptoms and finally death.

Identification. All of the loco weeds belong to the pea or bean family, and although the flowers are similar this similarity may not be easily recognized without careful examination. The loco weeds in Oregon have small white or cream colored or yellowish flowers in long clusters or spikes which in a few kinds finally produce rather large and inflated pods, in which the seeds very easily become loose when the pods become dry. The seeds rattle as the wind shakes the pods or as they are shaken by animals in passing. This gives rise to the common name, rattle weed. Not all loco weeds, however, have large inflated pods. The plants are low, spreading, having a cluster of finely divided leaves, usually coming from near the ground or along short stems. The small divisions of the leaves are borne along the side of a central leaf stalk as in a vetch plant. Just how many of the numerous loco weeds found within this State are poisonous, is not known.

Distribution and Habitat in Oregon. As has been previously stated there are many kinds of locos, which, all taken together, are found growing throughout the section east of the Cascade Mountains. They are also found in southwestern Oregon. As far as definitely known, however, the losses from locos have been rather localized in Eastern Oregon throughout the semi-desert and desert sections. The loco is usually associated with sage-brush. It is found more commonly in the deeper soil of the bottom lands and draws.

Preventive Measures. If horses were kept off the infested areas it would effectively prevent loco poisoning. Feeding alfalfa or other good hay during the dangerous season would do much to prevent the trouble. Yet these measures are not always practicable; there are certain sections where loco range land is the only land available for pasture. The pasture ranges in certain sections are very large, and the eradication of the loco plants from such areas is impracticable. Eradication, however, can be practiced with good results on smaller pastures. It has been shown that for the Rocky Mountains and Great Plains, it is not necessary to dig out loco weeds in order to kill them. If the locos are cut off two or three inches below the ground there is no danger that they will start up from the roots. This should be done when the plants are in flower, or before the seeds are formed. One man with a good sharp shovel can cut off the loco plants over a large area in two or three days. While tasks of this sort seem large, the financial outlay will prove to be a saving when the cost is compared with the loss that would otherwise be sustained.

It should also be kept in mind that the locos are propagated by seed, and that the seeds do not all germinate the same season of the year nor the same year, so that it is necessary to go over the field two or three times in one year and to repeat the process during the succeeding years until the plants are entirely eradicated or reduced to a point below the danger mark. Such a policy is practicable for each rancher independent of the attitude taken by his neighbors, because the seeds of the loco are not scattered by the wind. Through diligent and watchful effort, any rancher may have a loco-free pasture for his horses although loco may be growing all around him.

All animals that have acquired the habit of eating loco weed should be removed from the pasture if possible, in order that other stock, especially young animals, will not acquire the same habit through imitation.

Symptoms of Poisoning. "Symptoms are more pronounced among horses and cattle than among sheep. The general symptoms are erratic movement, constipation, progressive emaciation. Effects are chronic, extending over a time varying from a few weeks to two or three years. Deaths ordinarily result from starvation, the animal ceasing either to eat or drink." (Marsh.[24])

Remedy. "The first principle is to supply good feed, give laxatives, and strychnine for cattle and Fowler's solution for horses." (Marsh.[24])

COMMON BRACKEN FERN

Pteridium aquilinum pubescens Underw.

Fern staggers is undoubtedly more common than any other trouble caused by poisonous plants in Western Oregon. The prevention of this disease by using good feed is so well understood that it seems safe to say that any owner of horses can absolutely prevent fern staggers.

Common Name of Plant. The "fern" is the most common appellation given to the bracken fern. The common names, horsetail fern, mares-tail, etc., apply to a different fern, which is sometimes responsible for similar effects.

Animals Affected. This disease due to eating ferny hay is confined almost entirely to horses, although there are occasional reports that cattle have been poisoned by the fern. It is doubtful, however, whether fern staggers is of any importance except among horses.

The Extent of Poisoning. The dangerous sections may very easily be located by the amount of fern occurring in the hay fields. As most ferny hay is unsalable or undesirable it is usually fed on the ranch where it is cut. Fern staggers is therefore largely confined to the ferny districts. Fern staggers appears to be more prevalent in dry seasons than others, probably because of the shortage of good hay. Fern staggers has been known in Western Oregon since pioneer days, and still continues. Every year a considerable number of horses either become sickened or die of fern staggers. So common is this trouble that it becomes very important for every farmer or others feeding horses to know the fern and what constitutes "ferny hay."

Conditions of Poisoning and Quantity Required to Poison. There is very little good evidence that horses or other stock are commonly poisoned on fern in pastures. Although this may occasionally happen it is of so little consequence that the prevention of this disease is almost entirely confined to the feeding of horses at the stall. Ferny hay is usually rated as dangerous when it contains about one-third of the common bracken fern. The fern is a slow-acting poison so that the non-appearance of the disease when a little ferny hay is fed is all the more dangerous, because it gives rise to the impression that the danger point has not been reached or that the hay being fed is entirely safe. It usually requires about a month of feeding upon ferny hay to cause fern staggers, although the conditions leading to this poisoning are not entirely understood, and exceptions to this general statement are sometimes found. Fern staggers is most common during dry years when the best hay is sold and the farmer retains the poorer hay for his own stock.

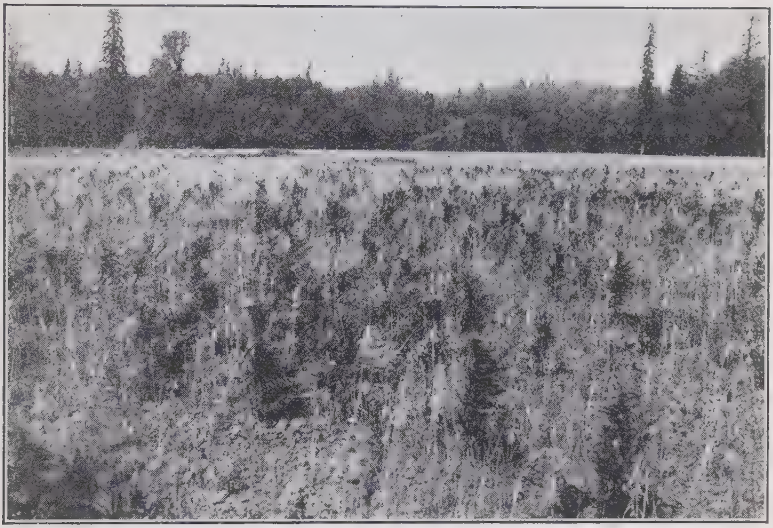

Fig. 9. A ferny hay field. (See Fig. 10.)

When is the Fern Poisonous? Ferny hay is dangerous at any time of the year that it is fed. The largest number of losses, however, occur from August through fall and during the winter, following the season of hay harvest.

Contrary to the common belief, fern poisoning is caused by a chemical poison that is found in the leaves and is not due to the presence of large quantities of spores or "rust" found on the under side of the leaves. This fact has been demonstrated by experimental feeding and appears to be well established.

How Can the Fern be Recognized? Almost every farmer knows the fern, and to him no further description is necessary. It is to the occasional purchaser of poor hay that the means of recognizing this plant

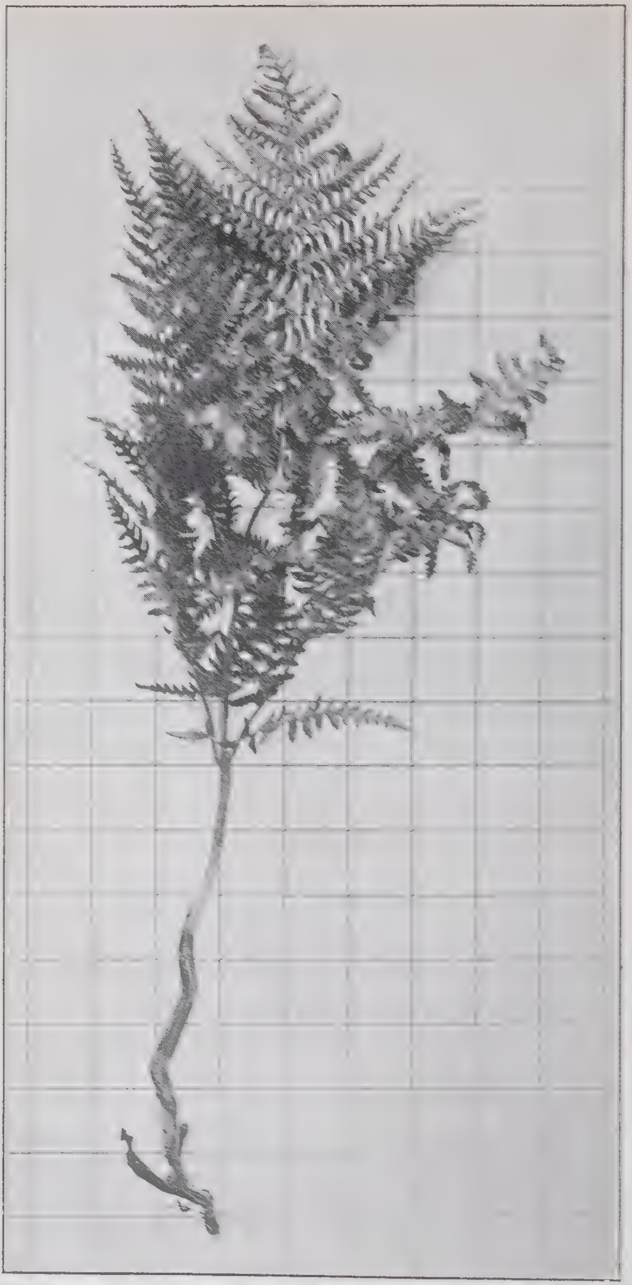

Fig. 10. The bracken fern (*Pteridium aquilinum pubescens* Underw.), showing leaf and a small portion of the horizontal underground stem.

should be given. An idea of the characteristics of the leaves of the common fern may be had by an examination of the accompanying illustration. It will be noted that all of the plant coming above the ground is one large leaf, which is very much divided. On the under side of this leaf will be found an over-turned margin, under which will be produced a large number of tiny rust-colored spore cases. The spores are produced in so large a quantity that the under surface of the fern leaves and often also the hay become coated with the brown powder. Even if the hay is cut before the spore-producing season it is just as dangerous as afterward. The brown powder due to these spores is commonly referred to as "rust;" it has no connection, however, with the disease of grain and other plants known as rust.

The stems of the fern grow horizontally and are all far underneath the surface of the ground. This fact makes eradication difficult.

Distribution and Habitat in Oregon. Although the fern, or bracken fern, is found growing throughout the mountainous districts of Oregon, it becomes of economic importance only west of the Cascades where it grows in sufficient abundance to cause fern staggers. The bracken fern may be found in almost any locality where a sufficient amount of moisture occurs and the soil is deep enough for the underground stems to grow. Fern staggers, however, is most likely to occur in the foothill section of the Cascade and Coast mountains. Ferny hay is sometimes shipped out of these sections and causes poisoning in unexpected places.

Preventive Measures. Here, as in all other cases, prevention is the best cure. With good fern-free hay fed all the time there is never any trouble with fern staggers. Farmers report that when a sufficient quantity of good hay is fed along with the poorer quality and plenty of other good feed is given all the time, horses will pick out only the good feed and leave the fern, which may be thrown out of the manger each day and used for bedding. Horses are known to acquire a taste for the fern, however, when forced to it by lack of a sufficient quantity of good hay or by continual feeding upon ferny hay. When the taste for ferny hay is once acquired the practice of feeding hay with any fern should at once be abandoned. Under these conditions it is not possible to use the ferny hay for bedding, because the horse will eat even the bedding. Doctors S. Hadwen and E. A. Bruce[17] state: "The affected horses in nearly all cases received but little else than hay in the shape of food; where animals were given plenty of hay and roots with occasional feeds of bran and oats, no trouble of this nature occurred."

Symptoms. Doctor B. T. Simms, Professor of Veterinary Medicine at the Oregon Agricultural College, describes the symptoms and remedy of fern poisoning as follows:

"Not all the symptoms to be mentioned are necessarily seen in every case. The first thing noticed is usually a slight unsteadiness of the gait. At this time appetite, temperature, and condition of the bowels are usually about normal. The respiration may be somewhat faster than is normal. As the disease progresses the affected animal shows a typical loss of control of the muscles. The gait is very unsteady. The animal may push forward or stand with the head pushing against the manger. There is frequently a drowsy appearance. There may be some difficulty in taking food into the mouth and in swallowing. The appetite usually remains fairly good until the symptoms are very marked. The temperature frequently remains about normal. There may be some costiveness, but the bowels are not disturbed in a very high percentage of the cases.

"From seven to fifteen or twenty days after symptoms first appear the affected animals may go down. Those that get down usually die a few days afterward.

"**Treatment.** This will vary somewhat according to the symptoms existing. For this reason a veterinarian should always be called if there is one in reach. Moreover, this should be done as soon as symptoms appear. Skillful treatment will save a very high percentage of these cases if it is given in time. It is usually impossible to save them, however, if they have been showing symptoms for ten to fifteen days before the veterinarian reaches them. If no veterinarian is to be had the animal should be given a purgative such as a quart of raw linseed oil. All ferny hay should be taken away immediately. Bran mashes, good clean hay, and perhaps some carrots may be given as food. The animals affected should be kept as quiet as possible. Comfortable quarters should always be provided. Plenty of bedding should be placed under the animals and care should be taken that they are not exposed to the weather or to very cold wind."

MINOR POISONOUS PLANTS

Several other plants native to the State are known to cause poisoning of domestic animals. The lesser importance of these plants is due to their restricted geographic distribution or to their occurrence in places where stock rarely graze. Some of these plants are poisonous only for a short period of the year, while others are rarely eaten because of their repulsive taste or smell. No attempt has been made to discuss these plants in the order of their importance, because there is little known concerning the actual extent of their injury to domestic animals.

SHRUBS

Menziesia. Menziesia or fool's huckleberry *(Menziesia glabella* Gray*)* is poisonous to sheep if they eat a sufficient quantity of it. It grows in the mountains and is most likely to be eaten along driveways, trails, and around bedding grounds after the good feed has been eaten off. If sheep herders will follow the plan of using different trails or driveways and different bedding grounds each night no trouble is likely to occur.[26]

Black Laurel. There are two plants referred to in California as the black laurel, although they are quite different in appearance. One of these, *Ledum glandulosum* Nutt., occurs in the mountains of Oregon. It is known to be poisonous to sheep, and there seems to be no question that it is the cause of serious losses in California. The extent of losses in Oregon is not known.[26]

White Laurel or Large Azalea. *(Rhododendron occidentale* Gray.*)*[26] This plant is found in the mountains at lower elevations than the black laurel and is poisonous to sheep. Sheep have been poisoned in Oregon on this plant when brought into new or unfamiliar areas. Wherever losses have occurred they should be reported to the Oregon Agricultural College Experiment Station.

The Small Azalea. *(Rhododendron albiflorum* Hook.*)* This plant is found in the mountains of the Northwest, and although not generally recognized as a poisonous plant is responsible for some losses among sheep. It is believed to be more poisonous than the Menziesia and less poisonous than the black laurel.

The United States Department of Agriculture[26] gives the following symptoms and recommendations for treatment:

"The symptoms are practically the same in all cases of laurel poisoning. There is salivation, resulting in frothing at the mouth, nausea, ordinarily accompanied by vomiting, depression, weakness shown by a staggering gait or inability to stand, and irregular respiration. Grinding of the teeth is frequently noticed in sick animals.

"Little can be done in the way of remedial treatment. Anything that will aid in elimination will be of some benefit, and to this end purgatives may be given such as Epsom salts in doses of four ounces. The main reliance, however, must be placed on prevention. Herders should learn to recognize and avoid the plants."

Western Choke-cherry.[26] The leaves of the Western choke-cherry, *Prunus demissa* (Nutt.) Diet., are known to cause poisoning in sheep, although the conditions under which poisoning occurs are not well understood. A few sheep are likely to become poisoned if they are driven along driveways lined with this shrub. Such places should be carefully avoided by sheep herders, both as driveways or bedding grounds. The poisonous principle acts very quickly, and there is usually little that can be done to save poisoned animals.

"Poison Oak." *(Rhus diversiloba* T. and G.*)* This is not a stock-poisoning plant and in some places is regarded as valuable forage.

Mistletoe. This parasite *(Phoradendron villosum* Nutt.*)* so commonly found upon the oaks in some parts of the State is rarely accessible to cattle. It is said that they are very fond of it, however, and if by any chance they get an opportunity, will eat it greedily.

Rabbit Brush. A number of plants in the sage-brush desert country are called rabbit brush. The one referred to in this article is technically called *Tetradymia glabrata* Gray. Losses of several thousand head of sheep in Nevada[5] have been reported, and as this plant has been found growing in Oregon it is thought best to mention it here. If any losses within the State have occurred, it is urged that they be reported to the Oregon Agricultural College Experiment Station. This rabbit brush is found growing on the sage-brush areas along with the bud sage, white sage, shadscale, salt sage, and the green sages. Fatal results are reported in the spring when there is little else to eat and sheep have been forced to graze upon the young buds and leaves almost exclusively for some time, until the stomach is nearly full. This situation cannot occur unless the sheep are very hungry due to lack of other feed. Cautious herding and a good supply of other feed are suggested as preventive measures.

HERBACEOUS PLANTS

Common Horsetail. *(Equisetum arvense* L.*)* The poisonous nature of horsetail or mares-tail is very much like that of the bracken fern. Like the fern, horsetail is injurious when found in hay. It grows abundantly on moist bottom lands, and often proves to be a bad pest in alfalfa, oats, or other hay crops.

Staggers caused by the horsetail fern (often called "rush") frequently occurs among horses.

The poisonous effects are usually slow to appear. The conditions causing the disease, its prevention, symptoms, and treatment are similar to fern staggers caused by the bracken fern and mentioned on pages 33-34.

Milkweed. Sheep and cattle are sometimes driven by excessive hunger to eating the different milkweeds. Although they are very distasteful when green, the milkweeds are readily eaten when dry because the bad flavor has disappeared.[7] Most of the losses are due to the narrow-leaved milkweed or Mexican whorled milkweed *(Asclepias mexicana* Cav.*)*, which is poisonous at all stages of growth either green or dry. The leaves are the most poisonous part of the plant, with the stems and pods next in order. The dried milk is very poisonous. The narrow-leaved milkweed is of far greater importance[7] as a poisonous plant than the showy-leaved milkweed *(Asclepias speciosa* Torr.*)*, and the dried plant contains little of its original poisonous substance. Both milkweeds occur in Oregon. The whorled milkweeds of the Rocky mountain region[12 33 35] are not reported for this State.

There is no known medicinal remedy. The milkweeds are poisonous at all times, and the dead standing narrow-leaved milkweed is poisonous in the winter or in hay. It is believed that horses[33‡] as well as sheep and cattle may be poisoned by the Mexican whorled milkweed.

Stock should be kept away from milkweed patches or kept on pastures where the feed is sufficient to maintain the animals in good condition and to prevent hunger.

Aconite. Aconite *(Aconitum columbianum* Nutt.) has long been regarded as a poisonous plant. It is known to contain a poison, but experiments by the United States Department of Agriculture indicate that aconite does not cause stock poisoning on the range.[26] (Page 10.) The tall larkspur which looks somewhat like aconite renders a grazing ground dangerous while aconite does not.

False Hellebore. This plant, *Veratrum californicum* Durand, is more often called "skunk cabbage" than false hellebore. This is not to be confused with the true skunk cabbage. The false hellebore is commonly found in the mountains in Oregon. Fatal poisoning rarely occurs except among young sheep, but older sheep are sometimes made very sick. As one sheep herder expressed it, "sheep lie down all day, travel next day." In order to avoid poisoning, sheep should be allowed to eat the "skunk cabbage" only in small amounts if at all.

Vetch. Dr. W. H. Lytle, State Veterinarian, reports[21] that poisoning of cattle is quite prevalent throughout the vetch-growing sections of Oregon. The feeding of ensilage is recommended as an antidote and an appetizing food. Animals affected with vetch poisoning lose their appetite.

Vetch should be cut before it has become over ripe and heavily podded, whether it is to be used as hay or for ensilage. Vetch hay should be fed with caution.

Tar Weed. This name is applied to a very common weed in the wheat fields and waste places of Eastern Oregon. There is a general belief that the tar weed, *(Amsinckia intermedia* Fisch. and Mey*)* causes the walking disease among horses. Whether this plant is responsible for the sickness has never been definitely established. Until the tar weed is definitely determined to cause the sickness no recommendations should be made. For the present all that it is safe to say is that mules appear to be immune, and on this account they are rapidly replacing horses in the drier wheat-growing section of the State.

Arrow-grass *(Triglochin maritima* L.*)* has been recently reported as the cause of death in sheep and cattle in Nevada.[c]

Arrow-grass grows in the marshes along the Oregon seacoast and in the interior salt marshes. Although no cases of poisoning caused by this plant have been found or reported to the Experiment Station, it is thought best to call attention to the poisonous nature of the plant.

Hay should not be cut where arrow-grass grows abundantly, nor hungry stock allowed to graze in pastures where it grows.

The leaves of arrow-grass are poisonous throughout the entire life of the plant and also when cured with hay. No medical cure is known.

Foxtail Grass. This grass is not poisonous, but the long barbed beards cause mechanical injuries to sheep, horses, and cattle. The beards or awns are covered with sharp barbs, as anyone may prove by pulling one between the fingers. The squirrel-tail or foxtail grass *(Hordeum jubatum* L.*)* is a common weed in the irrigated sections of the State as well as on the lower moist meadows.

The chief trouble occurs when foxtail is present in hay. The barbed awns work down between the teeth, causing sore gums. They become entangled in the wool about the eyes of sheep, working under the eyelids and even into the eye-ball, causing blindness in sheep. Cases have been reported where the awns worked through the palate and into the nasal passages. Awns found working their way into the flesh of animals should be pulled out.

Foxtail is an annual grass. Control measures must therefore center about eradication to prevent seed production. This can only be done by cultivation with springtooth harrow, by frequent cuttings of infested fields, or if the field is very badly infested by plowing up and clean cultivating. Foxtail is said to indicate excessive irrigation. Where this seems to be true irrigation can be reduced.

The downy brome *(Bromus tectorum* L.*)* also causes similar injury when found in hay. The downy brome is sometimes called "cheat grass."

St. John's wort is found throughout the timbered and grass sections of Oregon, but is especially abundant in Western Oregon. This plant is also called goat weed and Tipton weed. Cases of poisoning have been reported to this Station.

St. John's wort *(Hypericum perforatum* L.*)* will cause an irritation of the skin of sheep, horses, cattle, and goats when they are forced to eat the plant.* Animals chiefly affected are those with unpigmented skin or unpigmented spots or patches of skin, when exposed to the sun. Cloudy days or shelter is often sufficient to prevent the irritation. From forty-eight hours to three weeks, according to the age of the plant eaten or the amount of sunshine, are required before the symptoms of poisoning are noted. The exposure of unpigmented skin to sunlight causes the development of sores and scabs that itch. The itching sensation causes the animals to scratch, rub, bite, or lick the affected parts, and in severe cases to run as if mad. In both cattle and sheep there is a loss of condition, in milking cows there is a suppression of milk, and the value of the wool of sheep is seriously lowered on account of an interference with growth.

Western Sneeze Weed *(Helenium hoopesii* Gray*)* causes the "spewing sickness" of sheep and is poisonous to cattle.[34] The plant grows in the Stein mountains and possibly in other sections of Eastern Oregon. No cases of poisoning have been reported to the Oregon Agricultural College Experiment Station. In other western states where the sneeze weed has become dangerous, the spread of the weed has followed a depletion of the range due to overgrazing. No medicinal remedy has been found. It is difficult to exterminate, and the restoration of an overgrazed range is very slow. For these reasons continued care should be observed to avoid overgrazing where the sneeze weed has obtained a foothold.

FUNGI

Toadstools. Toadstools of various kinds have been reported as causing the death of many sheep and goats in the timbered regions of the State.

Moldy hay. Almost any moldy feed will cause poisoning. Improperly cured alfalfa or other hay will mold. The same is true of hay and straw in the stack if exposed to the weather in such a way that it becomes wet. Moldy hay usually has a musty smell and should not be fed.

Ergot. Ergot is very common on several of the wild grasses of the State, especially upon the wild rye-grasses. The conditions are such that these ergoted heads are rarely eaten, however, and no serious damage results.

FORAGE POISONING

Spoiled hay or ensilage infested with molds or certain bacteria may cause forage poisoning in horses, cattle, or mules, which are usually affected in the order named.

Forage poisoning is also called "blind staggers," cerebrospinal meningitis, etc.

When feed is kept under improper moisture conditions a growth of molds or bacteria may develop which may give rise to toxic substances that cause forage poisoning.

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*Dodd, Sydney,
1920. St. John's wort and its effects on livestock.
Agricultural Gaz. N. S. Wales 31:265-272. April 3, 1920.

The bacterium known as *Bacillus botulinus* has been shown by investigators[14] [15] [16] [38] in the central United States to cause forage poisoning. This organism is responsible for a similar disease in man called "botulism."

There is no reliable medical treatment, but some animals may be saved by the use of purgatives. No mouldy or spoiled forage or ensilage should be fed to stock because of the danger of forage poisoning, which is usually fatal to horses and mules.

POISON SPRAYS

Cover crops grown in orchards where lead arsenic spray has been used have been the cause of fatal poisoning in horses. The horses ate hay cured in the orchards.

Weeds sprayed with arsenic sprays for the purpose of eradicating them have also been fatal to cattle. In fact any stock will become poisoned unless kept away from such dangerous applications of poison sprays.

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In Cooperation with

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Office of Cereal Investigations

The Wheat Bunt Problem in Oregon

By

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and

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CORVALLIS, OREGON

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RECOMMENDATIONS

Farmers of Oregon lose thousands of dollars annually from the treatment of seed for bunt because of seed killed or injured by treatment and the consequent thin stands of wheat. As shown in this bulletin, these losses may be reduced to a minimum by:

(1) Sowing clean, plump seed which has been fanned and all foreign matter, smut balls, and most of the cracked and injured kernels removed.

(2) Treating the seed by the bluestone-lime method. Use 1 pound of bluestone to 5 to 10 gallons of water, dip 5 minutes, drain 15 minutes, and dip in milk of lime (1 pound of lime to 10 gallons of water). The stronger solution is advisable only when seed is sown in bunt-infested soil. Always wash bluestone-treated seed in lime water.

(3) Treating seed with a formaldehyde solution of 1 pint of commercial formaldehyde to 40 to 45 gallons of water. Dip 3 to 5 minutes, drain, and plant within 24 hours in soil sufficiently moist for prompt growth. For sowing in dry soil, or if treated seed is to be stored for any period of time, the bluestone-lime method is preferable. Good results with formaldehyde-treated seed can be secured by treating the seed one day and sowing it the next. Read pages 25 to 32.

Several highly bunt-resistant wheats which can be safely sown without seed treatment have been discovered at the Sherman County Branch Experiment Station. See pages 37 to 42.

The Wheat Bunt Problem in Oregon*

By D. E. STEPHENS and H. M. WOOLMAN

I. EFFECT OF CHEMICAL SEED TREATMENT ON THE CONTROL OF BUNT AND ON SEED GERMINATION

Bunt, or the stinking smut of wheat, has undoubtedly been the cause of a greater aggregate loss to the world than any other crop pest. Rusts, Hessian fly, chinch bugs, and other enemies have from time to time caused immense losses, but the ravages of each of these have been somewhat restricted in area and to some extent sporadic in character, while the bunt has steadily taken its toll in all localities where wheat has been grown throughout the centuries that this cereal has been the world's principal bread crop. The losses due to it fall not alone on the wheat grower, but extend to all who eat bread. In addition to the direct loss in yield, there are the indirect losses due to the befouling of the threshed grain, the expense of treating the seed, and the actual loss of seed due to the effect of the fungicide on the viability of the grain.

WHAT CAUSES SMUT?

The cause of the disease is a microscopic fungous plant which may belong either to the species *Tilletia tritici* or to the species *Tilletia levis.* The two cannot be distinguished by the ordinary observer and can only be identified with certainty by the use of the microscope. The so-called bunt ball or button, which appears where the grain of wheat should be, is composed of about four million spores or reproductive bodies analogous in their functions to the seed of a flowering plant. When kept dry, these spores retain vitality for several years. Spores twelve years old have been found to germinate. In moist soil, they germinate in from four to eight days, the exact time being governed by the soil temperature and degree of soil moisture. The eventual result of their germination is the production of an infection thread which, coming in contact with the underground parts of a young wheat plant, may, by some means not fully understood, bore its way into the plant tissues. If it finds the host plant congenial, that is to say, if it is a susceptible variety of wheat, it proceeds to make its way to the growing point, the young head, where it will persist and spread as the head grows until the time when the wheat kernel should begin to form. It then assumes entire control of the growth of the kernel, generally preventing the fertilization of the ovary by killing the stamens, or male organs of the plant. It absorbs all the food elements which the wheat plant ordinarily provides for seed formation, converting the food to its own use, the formation of smut spores.

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* This bulletin is a progress report of cooperative experiments that have been conducted in Oregon by the Oregon Agricultural College Experiment Station and the United States Department of Agriculture relating to the wheat bunt problem. The work reported herein includes methods of seed treatment, and the search for and production of wheat varieties immune or highly resistant to the disease. During the course of the investigations, a number of different people have assisted in the work and in various places in the text reference is made to the assistance rendered by these people. All pathological work has been under the direct supervision of Dr. H. B. Humphrey, Patholigist in charge of Cereal Diseases, United States Department of Agriculture, and Prof. H. P. Barss, Pathologist, Oregon Agricultural College Experiment Station. The wheat breeding work has been supervised by Dr. C. R. Ball, Cerealist, United States Department of Agriculture; J. Allen Clark, Agronomist in charge of Western Wheat Improvement, United States Department of Agriculture; and George R. Hyslop, Farm Crops Specialist, Oregon Agricultural College Experiment Station.

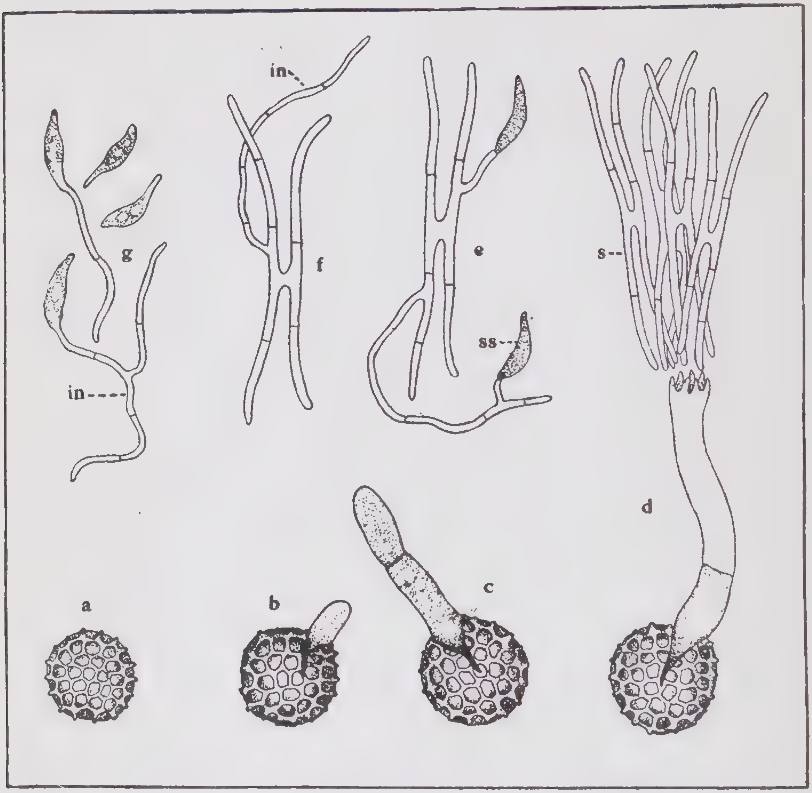

Fig. 1. Various stages in the germination of spores of stinking smut, *Tilletia tritici.* *a,* Spore surface showing characteristic reticulate ridges; *b,* spore in early stage of germination with young promycelium protruding from the ruptured spore wall; *c,* a later stage in the formation of the promycelium; *d,* mature promycelium with a tuft of H-shaped sporidia, *s,* borne in its summit; *e,* a separated sporidium which has produced secondary sporidia, *ss; f,* a separated sporidium which has given rise directly to an infection thread, *in; g,* several secondary sporidia which have started to germinate or have produced infection threads. (From Wash. Exp Sta. Bul. 126.)

METHODS OF DISTRIBUTION

In the threshing process, many bunt or smut balls become broken and a part of the spores become so persistently attached to the grain to which they adhere that no mechanical method of cleaning will remove them without destroying the viability of the grain. The spores present on the seed will cause a bunted crop if sown without chemical treatment. A large part of the spores, however, are blown from the thresher and scattered broadcast for miles. Where these settle on summer-fallowed ground already prepared for seeding, they are a more serious menace than the seed-borne spores, as no treatment will prevent infection from them if the crop is sown soon after the first fall rain, as it usually is when summer-fallowing is practiced. The spores begin to germinate as soon as the soil becomes moist, and will be in a condition to infect the young wheat plants for at least a month thereafter. The infection can take place in the young plant anywhere between the seed and the surface of the soil.

Since the time when fairly satisfactory methods of seed treatment were worked out, from twenty to thirty years ago, the central and eastern parts of the United States have had but small losses from bunt except where the growers neglected to treat their seed. In the Pacific Northwest, however, the wheat growers have continued to suffer great losses notwithstanding the fact that seed treatment was universal and usually thorough. Up to a few years ago this state of affairs was a mystery. The explanation was discovered at the Washington Agricultural Experiment Station at Pullman, between the years 1913 and 1917.*

It was found that bunt prevalence in the Pacific Northwest was inseparably connected with the summer-fallow system of farming. It was also found that in certain years more than forty thousand bunt spores per square inch settled on the fields in the vicinity of Pullman, Washington, during the threshing season, and that in certain cases as high as 60 percent of bunt appeared in the crops due to these wind-disseminated spores alone. It is true that in Oregon this annual spore fall is much less than in the Palouse country of southeastern Washington and northern Idaho, but it is sufficient in some localities to cause considerable loss.

Wind Dissemination of Bunt Spores. During the harvesting and threshing season of 1918, an investigation was undertaken to determine the extent of bunt-spore fall in Oregon.

Spore traps were installed at several points in Eastern Oregon and placed under the care of local people.† After threshing had been finished, the contents of these traps were collected and counted by the junior writer. Table I shows the location of traps and number of spores falling per square inch.

On August 6, Messrs. Bell and Kearns collected leaves from trees at intervals along the road from Pendleton to La Grande. The leaves were examined and the spores adhering to them estimated by Miss Jessie P. Rose at Corvallis. Spores were found on them all, the number decreasing in inverse ratio to the distance from Pendleton. The road crosses the Blue Mountains at an elevation of about 4000 feet and spores were found on the top. Another collection was made by the same persons on the road from Elgin in the Grande Ronde Valley to Walla Walla, Washington; spores were found on all collections, but they were comparatively few in number.

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*Heald, F. D. and Woolman, H. M. 1915, Bunt or Stinking Smut of Wheat. Wash. Agr. Exp. Sta. Bul. 126, p. 24, fig. 5.

†Assistance in collecting bunt spores was rendered by the following persons: Harry Key and C. C. Calkins, Moro; J. H. Padburg, Heppner; Geo. White, Lexington; Bernal Hug, Elgin; Robt. Withycombe, Union; Blanch Strode, Mikkalo; Rose Anderson, Condon; Dr. Campbell, Cold Springs; Mr. Coppeck, Athena.

TABLE I. NUMBER OF BUNT SPORES TO THE SQUARE INCH COLLECTED AT SEVERAL LOCALITIES IN OREGON BETWEEN JULY 8, AND SEPTEMBER 24, 1918

Date	Locality	Total number of spores per sq. in. during season
August 10 to August 31	Moro	77
August 31 to September 8	Moro	216①
August 22 to September 10	Moro	75②
August 22 to September 13	Moro	30
August 1 to August 24	Heppner	152
August 1 to August 27	Lexington	73
August 5 to September 24	Elgin	560
August 7 to October 2	Union	190
July 17 to September 16	Mikkalo	2500③
July 17 to September 16	Condon	122
July 17 to August 27	Pilot Rock	1005
July 8 to September 6	Cold Springs	1570
July 8 to August 18	Athena	4466

① Stacking straw close to trap during this period.

② In bean field. Wheat field 20 rods on east and ¾ mile on southwest.

③ Along side of road and near elevator and railroad sidings. The number collected here is probably much more than would have been caught in the neighboring fields.

An observation that clearly shows the great distance that these spores may be transported by the wind was made by the junior author at the town of Haines in the North Powder Valley. Cottonwood leaves collected here on August 5 had adhering to them from 200 to 500 spores to the square inch of surface. At the time the leaves were collected the nearest possible point of origin was the wheat region west of the Blue Mountains around Pendleton, where harvesting had been in operation since about July 4. These spores had evidently been picked up by the wind at an elevation of 1000 to 1500 feet, carried 100 miles to the east, over the Blue Mountains 4000 to 5000 feet high, and finally deposited at an elevation of 3300 feet, the altitude of Haines.

REMEDIES

The results of the investigation above referred to made it evident that the wheat bunt pest in the Pacific Northwest could be controlled only by an entire change in the system of farming or by the production of varieties of wheat immune or highly resistant to the disease. Seeding before the threshing season and replowing the summer fallow after, thus burying the spores below the seed bed, or very late seeding are available remedies under certain conditions; but for obvious reasons all are inapplicable as general methods. Soil treatment for the infection would be impracticable on account of the expense. The Experiment Station workers of Moro and Corvallis and the cooperating agents of the United States Department of Agriculture were therefore convinced that the permanent solution of the problem could only be reached through the production of resistant varieties. The principal part of their work on this problem for the last few years has been directed to this end and it is now felt that it is only a question of time when all the susceptible varieties of wheat now grown in Oregon can be replaced by immune or highly resistant ones having all other desirable qualities. In fact, there are now in the experimental plots about twenty varieties of several different types ranging from hard red to soft white, any of which could be safely sown without treatment. Some of these immune varieties are certainly unsuitable for commercial growing in Oregon but are of unquestioned value as parents for new hybrid varieties. Even if there were discovered and developed from among these immune and resistant wheats, however, varieties that would be entirely satisfactory for each of the different types of soil and climatic conditions of Oregon, several years would have to elapse before they could be fully tested and increased sufficiently to supply the demand. It is likely that further crosses will have to be made before the ideal types of wheat are obtained. Since in the meantime seed treatment must continue, search for improved methods of treatment has not been neglected.

GEOGRAPHIC DISTRIBUTION AND COMPARATIVE VIRULENCE OF *TILLETIA TRITICI* AND *TILLETIA LEVIS*, THE ORGANISMS CAUSING BUNT

East of the Rocky Mountains *T. levis* is the species generally found, though in some localities both are found occasionally. Both are frequently found in Michigan. West of the Rockies, *T. tritici* is by far the more prevalent. According to Professor W. W. Mackie, of the University of California, it is practically the only species found in California. The two occur in Western Oregon, and in the Willamette Valley in particular, where they are about equally abundant. In the wheat belt of Eastern Oregon and Washington and Northern Idaho, or what is generally called the Inland Empire, *T. levis* has not been found in the field. It does, however, occur in Southern Idaho, notably around Pocatello, where in 1918 it was found by the junior writer in wheat stored in warehouses.

Why *T. levis* has not spread from Western to Eastern Oregon is a matter for conjecture. It has been suggested that the two forms have special soil and climatic adaptations. Experiments in Oregon have furnished little, if any, support for this theory.

To determine the relative virulence of *T. tritici* and *T. levis* under different soil and climatic conditions, lots of twenty-one varities of wheat were first treated with formaldehyde, dried and divided into two portions, one of which was heavily infested with spores of *T. tritici* and the other with *T. levis.* These lots were further divided and planted in the fall of 1918 at Corvallis, Moro, Hermiston, Union, and Medford. Unfortunate conditions at all these places except at Moro prevented the obtaining of complete records from the resulting crop. Reliable records for nine varieties were obtained both at Corvallis and Moro; viz., Pacific Bluestem, Marquis, Jones Fife, Little Club, Banner Berkeley, Unknown, Red Rock, Alberta Red, and Turkey No. 889.

Reliable records for the following six varieties were obtained at Hermiston: Jones Fife, Banner Berkeley, Unknown, Red Rock, Alberta Red, and Turkey No. 889. Reliable records were also secured at Medford for Fortyfold, Turkey (Washington No. 326), and four varieties of Little Club and Fortyfold hybrids produced by Superintendent Withycombe of the Eastern Oregon Branch Experiment Station. No records of these six were obtained except at Medford and Moro.

The average results are given in Table II.

TABLE II. PERCENTAGE OF SMUTTED HEADS FOUND IN WHEAT VARIETIES SOWN IN THE FALL OF 1918 WITH SEED INOCULATED WITH SPORES OF *T. TRITICI* AND *T. LEVIS* AT CORVALLIS, MORO, AND HERMISTON, OREGON

Location	Number of varieties	Percentage of bunted heads	
		T. triciti	*T. levis*
Corvallis	10	44.1	57.2
Moro	20	40.0	26.3
Hermiston	12	42.1	40.5
Average		42.0	31.0

In the fall of 1919 the seed of eight varieties was prepared in the same manner and planted at Corvallis, Moro, Hermiston, Union, and Astoria. The results are given in Table III.

TABLE III. PERCENTAGE OF BUNTED HEADS IN EIGHT WHEAT VARIETIES SOWN AT FIVE PLACES IN OREGON IN THE FALL OF 1919, WITH SEED INOCULATED WITH SPORES OF *T. TRITICI* AND *T. LEVIS*

Variety	Percentage of bunted heads at:									
	Corvallis		Moro		Hermiston		Union		Astoria	
	T. tritici	T. levis	T. tritici	T. levis	T. tritici	T. levis	T. tritici	T. levis	T. tritici	T. levis
Hybrid 143	70.5	78.7	53.1	43.0	68.2	65.8	10.5	23.7	90.1	37.0
Fortyfold	42.5	60.4	67.9	34.9	13.0	38.0	①	①	48.3	40.4
Turkey No. 889	1.1	6.4	6.2	6.9	2.7	0.0	7.5	1.8	0.0	2.1
American Banner	29.4	27.7	52.6	37.7	34.1	22.9	20.0	24.9	8.6	5.7
Fulcaster	3.8	3.8	9.4	8.0	6.2	2.9	15.4	3.3	5.5	5.5
Alaska x Fife	14.0	16.1	1.2	0.7	0.0	0.0	17.2	0.8	5.2	6.9
Turkey (Wn. No. 326)	19.6	21.6	11.1	4.6	4.0	2.8	1.4	1.9	33.7	22.5
Florence	7.0	10.0	6.0	4.0	10.0	10.5	0.0	1.8	12.8	0.0
Average	23.5	28.1	22.2	17.8	17.3	17.9	10.3	8.3	25.5	15.0

①No plants.

In 1919 plantings were made at Corvallis, Moro, Hermiston, Union, and Astoria to test the comparative virulence of spores of both species, (a) produced under the humid conditions of Corvallis and (b) produced under the semi-arid conditions of Moro. The spores of either species showed practically equal virulence whether produced at Corvallis or at Moro. A planting was made at Corvallis of seed infested with a mixture of both kinds of spores. *T. tritici* heads predominated in the resulting crop.

In examination of this crop, the junior writer frequently found heads of both species of bunt in the same plant; in one instance *T. tritici* and *T. levis* were found in the same head.

These results certainly do not indicate that the failure of *T. levis* to invade the fields of the Inland Empire can be attributed to uncongenial soil or climatic conditions.

In the opinion of the authors, it is not necessary to assume special soil and climatic adaption to account for the non-spread of *T. levis* from the Willamette Valley to Eastern Oregon for two reasons. (1) The Cascade Mountains with their humidity probably form an effectual barrier to wind distribution. It is also true that *T. levis* does not pulverize as readily as

T. tritici but tends to break up into comparatively large aggregates in threshing and consequently inclines to settle near the thresher. (2) As different types of wheat are grown in Eastern and Western Oregon, the shipping of seed wheat from the Willamette Valley to east of the Cascades is probably infrequent, and when such shipments do occur, the seed almost certainly would be treated before planting, thus preventing the introduction of *T. levis* by seed-borne spores.

EFFECT OF SEED TREATMENT ON THE GERMINATION OF WHEAT AND CONTROL OF STINKING SMUT

In the autumn of 1912, observations made at the Sherman County Branch Station and elsewhere indicated that treating seed wheat for smut with a formaldehyde solution was responsible in many instances for thin stands of winter wheat.

Results in 1913. In order to determine the effect of the formaldehyde treatment on securing stands of winter wheat, in the fall of 1913 Turkey winter wheat was sown at Moro with a single-disk drill on August 26, in duplicate twentieth-acre plots, two inches and four inches deep. The strength of solution used was 1 pint of formaldehyde to 48 gallons of water, with a five-minute soak in the solution. Untreated seed also was sown in check plots. On November 5 careful stand counts were made on each plot, with the following results:

Shallow sowing, treated	83,000 plants to the acre
Shallow sowing, not treated	120,000 plants to the acre
Deep sowing, treated	37,000 plants to the acre
Deep sowing, not treated	84,000 plants to the acre

The experiment was repeated in duplicate plots on September 9 with a double-disk drill, with the following results:

Shallow sowing, treated	104,000 plants to the acre
Shallow sowing, not treated	140,000 plants to the acre
Deep sowing, treated	62,000 plants to the acre
Deep sowing, not treated	120,000 plants to the acre

In each instance the seed receiving no treatment produced considerably thicker stands than the seed treated with formaldehyde.

Results in 1914. In the fall of 1914, Turkey wheat was treated with bluestone (copper sulfate) and with formaldehyde. A careful germination test between blotters gave the following results:

	Percent germinated
Water soaked, 10 minutes	94
No treatment	92
Bluestone, 1 pound to 5 gallons, soaked 5 minutes	11
Formaldehyde, 1 pint to 48 gallons, soaked 5 minutes	28

Results in 1915. In the fall and winter of 1915, sixteen germination tests were made in the laboratory with wheat, oats, and barley treated with formaldehyde and with bluestone. Table IV gives the results obtained.

TABLE IV. PERCENTAGE OF GERMINATION, WHEAT, OATS, AND BARLEY, TREATED AND UNTREATED

(a) Percentage of germination on different dates of Turkey winter wheat not treated and treated with formaldehyde and bluestone on November 10, 1915, and placed in germinators the same day.

Date	Treatment					
	Water soaked 10 min.	Formal. 1 to 48 10 min.	Formal. 1 to 40 10 min.	Formal.① 1 to 40 10 min. washed	Bluestone 1 to 5 gal. 10 min.	Bluestone 1 to 5 gal. 10 min. washed
	%	%	%	%	%	%
November 17	88	74	67	82	20	33
November 18	92	76	74	85	24	54
November 19	94	83	76	88	29	70
November 20	94	85	80	90	31	73
November 22	97	86	83	92	35	76
November 23	97	87	84	92	38	78
December 29	97	92	95	94	74	95
December 29	97	92	95	94	74	95

(b) Percentage of germination on different dates of plump and shrunken seed of Turkey wheat treated with formaldehyde 1:48 and soaked ten minutes on December 30 and placed in germinators the same day.

Date	Plump	Shrunken
	%	%
January 5	90	88
January 7	97	94
January 11	97	96
January 18	97	96

(c) Percentage of germination on different dates of Sixty Day Oats not treated and treated with formaldehyde and bluestone on November 10, 1915, and put in germinators the same day.

Date	Treatment			
	Dry—no treatment	Formaldehyde, 1:40 ten min.	Bluestone 1:5 gallons ten min.	Bluestone 1:5 gallons ten min. washed
	%	%	%	%
November 17	28	18	6	49
November 18	33	22	13	49
November 19	51	39	21	51
November 20	62	49	29	52
November 22	79	54	35	57
November 23	80	55	38	57
December 29	88	89	79	89

① In the tables of this bulletin the strength of formaldehyde solutions is expressed in a ratio of pints to gallons, thus: 1 to 40 equals 1 pint to 40 gallons. Bluestone solutions are expressed in a ratio of pounds to gallons, as 1:5 equals 1 pound to 5 gallons.

(d) Percentage of germination on different dates of Sixty Day Oats not treated and treated with formaldehyde and bluestone on November 10, 1915, and put in germinators on December 30, 1915.

Date	Treatment			
	Dry– no treatment	Formaldehyde, 1:40 ten min.	Bluestone 1:5 gallons ten min.	Bluestone 1:5 gallons ten min. washed
	%	%	%	%
January 5	26	39	2	45
January 7	73	67	12	63
Janaury 11	100	77	20	75
January 18	100	80	45	75

(e) Percentage of germination on different dates of Maryland Winter Barley treated with formaldehyde on November 10, 1915, and put in germinators the same day.

Date	Treatment	
	Formaldehyde 1:40.	Formaldehyde 1:20.
	%	%
November 17	80	0
November 18	84	7
November 19	87	44
November 20	88	66
November 22	89	70
November 23	89	71
December 29	89	78

(f) Percentage of germination on different dates of Maryland Winter Barley treated with formaldehyde on November 10, 1915, and put in germinators on December 30, 1915.

Date	Treatment	
	Formaldehyde 1:40, ten min.	Formaldehyde 1:20, ten min.
January 7	88	0
January 11	88	0
January 18	88	3

It will be noted that in every instance the viability of the seed was injured by treatment and that the copper sulfate treatment was more injurious. In every instance washing or rinsing the seed in clear water increased the percentage of germination. In some instances the final count did not show any difference in the germination, but it will be noted that in nearly all cases there was delayed germination due to the seed treatment.

Results in 1916. In the fall of 1915, seed of Turkey winter wheat (C. I. 1558) was sown in damp soil on two dates at different depths. The first sowing was made on October 26, and the second sowing on November 5. Four lots of seed were used: (1) treated with formaldehyde, 1 pint to 40 gallons, soaked 10 minutes; (2) copper sulfate, 1 pound to 5 gallons, soaked 10 minutes; (3) no treatment; and (4) seed soaked in clear water for 10 minutes. The seed treated with formaldehyde and copper sulfate was in all cases sown first so there would be no chance for reinfection of the seed. Each lot of seed was sown at three depths, 1 inch, 3 inches, and 5 inches for the early sowing, and at two depths, 1 inch and 3 inches for the later sowing. The seed was not artificially infested with bunt, and, so far as could be observed, contained very little bunt infestation. Tables V and VI indicate the results obtained in 1916. The percent of

TABLE V. EFFECT OF VARIOUS SEED TREATMENTS AND DEPTHS OF SEEDING ON STAND AND SMUT INFECTION IN TURKEY WINTER WHEAT SOWN OCTOBER 26, 1915, AT MORO, OREGON

Treatment	Depth sown	Percent of stand	Number of smutted heads in one-hundredth acre
	in.	%	
Formaldehyde	1	81	2
Bluestone	1	76	0
No treatment, dry	1	110	14
Soaked in water	1	100	5
Formaldehyde	3	85	1
Bluestone	3	65	1
No treatment, dry	3	124	6
Soaked in water	3	100	4
Formaldehyde	5	88	5
Bluestone	5	61	0
No treatment, dry	5	141	16
Soaked in water	5	100	20
Average, formaldehyde	....	85	2.6
Average, bluestone	....	67	0.3
Average, dry	....	125	12.0
Average, water soaked	....	100	9.6
Average, 1 inch depth	....	92	5.0
Average, 3 inches depth	....	94	3.0
Average, 5 inches depth	....	98	10.2

TABLE VI. EFFECT OF VARIOUS SEED TREATMENTS AND DEPTHS OF SEEDING ON STAND AND ON SMUT INFECTION IN TURKEY WINTER WHEAT SOWN ON NOVEMBER 15, 1915, AT MORO, OREGON

Treatment	Depth sown	Percent of stand	Number of smutted heads in one-hundredth acre
	in.	%	
Formaldehyde	1	88	0
Formaldehyde and washed	1	126	0
Bluestone	1	82	0
Bluestone and washed	1	89	0
No treatment, dry	1	113	4
No treatment, water soaked	1	100	6
Formaldehyde	3	119	0
Formaldehyde and washed	3	99	0
Bluestone	3	86	0
Bluestone and washed	3	104	0
No treatment, dry	3	117	3
No treatment, water soaked	3	100	4
Average, formaldehyde	....	103	0
Average, formaldehyde and washed	....	112	0
Average, bluestone	....	84	0
Average, bluestone and washed	....	96	0
Average, no treatment, dry	....	115	3.5
Average, no treatment, water soaked	....	100	5.0
Average, 1 inch depth	....	99	1.6
Average, 3 inches depth	....	104	1.1

stand was obtained by dividing the number of plants per unit area for each treatment by the number of plants obtained from the seed soaked in water only.

These tables bring out the following points:

(1) For both early and late seeding, the thinnest stands were obtained from seed treated with copper sulfate. Washing seed treated with copper sulfate and formaldehyde increased the germination. For the late sowing there was no injury to the seed from the formaldehyde treatment.

(2) The thickest stands were obtained from the dry, untreated seed. This was partly due to the fact that more seeds actually were sown, though the drill was set to sow one-half peck less to the acre than for seed treated or soaked in water. The treated and water-soaked seed was not sown for two days after treating and was fairly dry when sown. It had increased in volume, however. No determinations of the actual increase in volume were made, but from later determinations it is estimated that the treated seed probably increased about 25 percent in volume.

(3) For both dates of sowing, the shallow seedings gave thickest stands.

(4) There was less bunt in the crop grown from seed treated with bluestone. There was more bunt in the earlier sowing. In the late sowing, there was no bunt from formaldehyde- or bluestone-treated seed. There was some bunt present in the wheat sown late and not treated, but not so much as in the early-sown wheat which had not been treated.

Results in 1917. In the fall of 1916, four plots of winter wheat treated with formaldehyde were sown in damp soil at the rate of 5, 6, and 7 pecks to the acre, and four plots of untreated seed were sown at the same rate on the same date. Careful stand notes were taken in the early spring of the number of plants on each plot. The number of heads on each plot was determined just before harvest and the number of bundles on each plot was counted when the grain was cut with the binder.

It will be noted from Table VII that there were practically twice as many plants to the acre on plots where the seed was not treated. A portion of this increase, however, was due to the fact that the untreated seed was sown dry and the rate of seeding, therefore, was thicker. Seed after being treated usually increases in volume from 20 to 30 percent. Allowing 30 percent for increase in volume of the treated seed, there was still a decrease of 18½ percent in the number of plants to the acre on account of the treatment with formaldehyde. In other words, 18½ percent of the seed was killed or at least did not emerge because of a ten-minute soak in a formaldehyde solution of 1 pint to 45 gallons of water. Table VII also brings out the point that the number of heads per unit area from the treated and untreated seed is not in proportion to the number of plants per unit area, the thin stands apparently tillering more. From the 8-peck rate, there were twice as many plants on plots where the seed received no treatment, but there were only 30 percent more heads and approximately 28 percent more bundles.

TABLE VII. YIELD AND OTHER DATA FOR TURKEY WINTER WHEAT SOWN ON DECEMBER 1, 1916, WITH SEED TREATED WITH FORMALDEHYDE, AND SEED NOT TREATED

Plot number	Rate in pecks	Stand			Number of bundles per plot	Yield in bushels per acre
		Plants per unit area	Heads per unit area	Culms per unit area		
1149W, treated	5	128	1190	1300	23	17.3
1147W, not treated	5	264	1216	....	33	20.0
1149E, treated	6	192	1114	1460	27	20.3
1147E, not treated	6	388	1292	1660	32	20.3
1150W, treated	7	200	1046	1450	30	21.0
1148W, not treated	7	380	1276	1607	38	20.6
1150E, treated	8	232	1114	1590	32	21.6
1148E, not treated	8	464	1452	1890	41	23.7

Results in 1918. A rather elaborate experiment was begun in the fall of 1917 at Moro and Corvallis, under the direction of Mr. C. W. Hungerford, to determine the effect of various seed treatments on securing stands of winter wheat and on controlling bunt. The counting of heads to determine the percentage of smut infection was done by Messrs. Hursh, Meier, and Bell. Mr. Bell also aided in making stand counts.

Nineteen different seed treatments were used on heavily bunted seed of Turkey and White Winter wheats. In addition to these treatments, check plots were sown with smutted and unsmutted seed of each variety that had been water soaked. The plots at Moro consisted of five drill rows, 8 rods long; and every fifth plot was a check plot. Turkey, C. I. 1558, threshed with the Station thresher, and White Winter, grown at Corvallis, were used in the experiment.

Table VIII shows the stand and the percentage of bunt obtained on each plot. The figures in the column "percentage of stand" were obtained by dividing the number of plants per unit area on each plot by the average number of plants per unit area on all check plots of each variety.

Table VIII brings out the following points:

(1) Formaldehyde and copper sulfate so injured the seed that stands obtained were much thinner than where these fungicides were not used. In general, the weaker the solution of the fungicide, the better the stand.

(2) Somewhat better bunt control was obtained from the use of formaldehyde than from the use of bluestone. The 1 to 50 solution of formaldehyde with a soak of ten minutes seemed to be as effective in controlling bunt as the stronger solutions of 1 to 40 and 1 to 20, or the longer periods of soaking.

(3) The Haskell method, besides showing some seed injury to the White Winter variety, did not control the smut in either the White Winter or Turkey varieties. This method consists of spraying the seed with a very strong formaldehyde solution and covering for varying lengths of time. It is not in general use and is not recommended for wheat.

(4) The Cresol method neither injured the seed nor controlled the smut.

TABLE VIII. STAND, AND PERCENTAGE OF SMUT IN TURKEY AND WHITE WINTER WHEATS GIVEN VARIOUS TREATMENTS WITH FORMALDEHYDE, BLUESTONE, AND CRESOL, AT MORO, OREGON

Treatments	White Winter		Turkey	
	Percent of stand	Percent of smut	Percent of stand	Percent of smut
Check 1, water soaked, clean seed	....	11	....	3.4
1. Formaldehyde 1 to 20, soak 10 minutes	46	4	31	.2
2. Formaldehyde, 1 to 40, soak 10 minutes	64	1	58	.4
3. Formaldehyde, 1 to 50, soak 10 minutes	69	.6	75	.7
Check 2, smutted seed, water soaked	....	96.0	....	28.0
4. Formaldehyde, 1 to 40, soak 10 minutes, covered 24 hours	65	3.0	43	0.0
5. Formaldehyde, 1 to 40, soak 10 minutes covered 2 hours	81	8.0	71	1.3
6. Formaldehyde, 1 to 40, soak 30 minutes, covered 2 hours	73	6.0	65	0.5
Check 1	....	24.0	....	....
7. Formaldehyde, 1 to 40, soak 60 minutes covered 2 hours	72	5.0	71	0.7
8. Haskell formula, full strength, 1 pint to 50 bushels, covered 5 hours	53	73.0	93	16.0
9. Haskell formula, half strength, 1 pint to 50 bushels, covered 5 hours	56	54.0	86	17.0
Check 2	....	88.0	....	22.0
10. Haskell formula, half strength, 1 pint to 50 bushels, covered 2 hours	71	67.0	81	12.4
11. Haskell formula, half strength, 1 pint to 50 bushels, covered 5 hours	59	58.0	88	23.0
12. Haskell formula, fifth strength, 1 pint to 50 bushels, covered ½ hour	47	24.0	95	17.5
Check 1	....	29.0	....	11.5
13. Haskell formula, fifth strength, 1 pint to 50 bushels, covered 2 hours	88	52.0	100	17.5
14. Haskell formula, fifth strength, 1 pint to 50 bushels, covered 5 hours	92	72.0	122	17.4
15. Bluestone, 1 to 5+salt, rinsed clear water	68	17.0	67	4.7
Check 2	....	86.0	....	25.0
16. Bluestone, 1 to 5 +salt, not rinsed	51	5.0	42	0.0
17. Bluestone, 1 to 5+salt, rinsed lime water	75	17.0	75	1.1
18. Cresol, 1 to 360	91	87.0	116	36.0
19. Cresol, 1 to 1000	107	86.0	97	21.0

Average number plants, treated, 188; average number plants, not treated, 374; average number heads, treated, 1116; average number of heads, not treated, 1309; average number bundles, treated, 28; average number bundles, not treated, 36.

Average yield, all rates treated, 20.1 bushels per acre; average yield, all rates not treated, 21.1 bushels per acre; average yield, five-peck rate, 18.6 bushels; average yield, six-peck rate, 20.3 bundles; average yield, seven-peck rate, 20.8 bushels; average yield, eight-peck rate, 22.6 bushels.

Results in 1919. In the fall of 1918 Turkey and Fortyfold wheats were sown in one-thirtieth acre plots, each variety being given twenty-five different treatments with formaldehyde and copper sulfate. Mr. J. C. Bell treated all seed and assisted in the sowing and taking of stand counts. Table IX shows the percentage of stand as compared with check No. 2, the percentage of bunt based on head counts, and the acre yield in bushels obtained from each plot.

The rate of sowing for the different treatments for each variety was ascertained by tying a small bag on the end of two drill tubes while drilling the whole length of the plot (150 feet). From the seed obtained from the two drill tubes, the actual number of pounds and kernels per acre was computed. This information is given in Table IX.

As is shown in Table IX, the average yield obtained from the three check plots, sown with clean, dry, untreated seed, was 27.5 bushels an acre from the Turkey variety, and 18 bushels an acre from the Fortyfold variety. The average yield obtained from all plots sown with formaldehyde-treated seed was 22.3 bushels an acre from the Turkey variety and 14.8 bushels an acre from the Fortyfold variety. The average yield from all plots sown with seed treated with bluestone was 24.3 bushels an acre from the Turkey variety and 15.1 bushels from Fortyfold. The average yield for both bluestone- and formaldehyde-treated seed was 23.3 for Turkey and 15.0 for Fortyfold. In 1919, therefore, there was a reduction in yield of more than 4 bushels an acre for Turkey wheat and of 3 bushels an acre for Fortyfold wheat because of seed treatment. The yield of the plots sown with smutted seed not treated, however, was only 20 bushels an acre for Turkey and 5.5 bushels an acre for Fortyfold, the latter variety containing 68.1 percent of smut as against 19 percent of smut for the Turkey variety.

The results obtained from this test, as shown in Table IX, and the results obtained in 1918, as shown by Table VIII, indicate that from 30 to 40 percent of the seed is so injured by the regular formaldehyde treatment that the plants never emerge and 40 to 50 percent of the seed treated with the usually recommended bluestone formula never comes up. While this item alone is important, it does not tell the whole story. The seed treated with either formaldehyde or bluestone seems to be so reduced in vigor that it does not come up until four or five days later than seed sown with no treatment. This was true for the seed treatment plots sown in the fall of 1917 and in the fall of 1918. Height measurements were taken on November 19, 1918, on 100 plants on each of the check plots, with the following results.

Treatment	Average height in mms. of 100 plants	
	Turkey	Fortyfold
Check 1, no treatment (dry)	53.5	67.3
Check 2, no treatment (wet)	54.5	69.3
Check 3, formaldehyde 1 to 40	51.5	58.0
Check 4, bluestone 1 to 5	44.8	51.0

TABLE IX. PERCENTAGE OF SMUT INFECTION, STAND AND ACRE YIELDS OF TURKEY AND GOLDCOIN (FORTYFOLD) WHEATS AFTER TREATMENT WITH VARIOUS SOLUTIONS AND SOWN AT MORO, OREGON, IN 1919

Method of treatment	Turkey				Fortyfold			
	Smut	Stand		Yield per acre	Smut	Stand		Yield per acre
		Plants	Heads			Plants	Heads	
	%			bu.	%			bu.
1. Check, clean seed, sown dry	1.3	105	107	27.5	7.3	115	104	18.0
2. Check, smutted seed soaked in water 10 minutes	19.1	100	100	20.0	68.1	100	100	5.5
3. Check, formaldehyde, 1 to 40, soaked 10 minutes	.7	56	95	25.0	5.7	57	84	16.5
4. Check, bluestone, 1 to 5, soaked 5 minutes	2.1	38	86	23.0	9.4	32	71	15.5
5. Formaldehyde, 1 to 20, soaked 10 minutes	9	38	83	22.0	12.3	33	37	12.0
6. Formaldehyde, 1 to 30, soaked 10 minutes	.3	50	87	22.0	2.1	52	83	11.5
7. Formaldehyde, 1 to 40, soaked 10 minutes, clean seed	.1	65	95	23.5	.7	58	72	15.0
8. Formaldehyde, 1 to 40, soaked 10 minutes, covered 4 hours	.4	62	98	22.0	.2	66	87	15.5
9. Formaldehyde, 1 to 40, soaked 10 minutes, covered 24 hours	.0	55	91	22.5	.2	64	104	15.0
10. Formaldehyde, 1 to 40, covered 4 hours, rinsed water	.0	52	90	19.5	.6	58	99	15.0
11. Formaldehyde, 1 to 40, sown at once	.1	62	90	22.5	.0	70	87	15.5
12. Formaldehyde, 1 to 50	.0	85	100	22.5	.7	86	99	15.0
13. Formaldehyde, 1 to 40, soaked 2 hours, no rinse	.0	58	92	22.0	.0	54	84	14.0
14. Formaldehyde, 1 to 40, soaked 2 hours, rinsed water	0	52	96	21.5	2.7	60	86	20.5
15. Bluestone, 1 to 1, sprinkle and sow at once	.0	28	81	24.0	1.5	20	77	15.5
16. Bluestone, 1 to 5, soaked 5 minutes, rinsed water	1.2	45	97	24.0	0	31	67	16.5
17. Bluestone, 1 to 5, soaked 5 minutes, rinsed lime water	1	41	93	24.5	2.2	36	78	14.5
18. Bluestone, 1 to 5, 1 pound salt, soaked 5 minutes, no rinse	0	29	95	23.5	.2	18	75	16.5
19. Bluestone, 1 to 10, soaked 5 minutes, no rinse	1.4	41	94	25.0	5.4	38	88	15.5
20. Bluestone, 1 to 10, soaked 1 hour, rinsed lime water	1.0	48	90	23.5	4.0	39	90	14.5
21. Bluestone, 1 to 10, soaked 1 hour, no rinse	1.3	32	82	23.5	5.4	32	72	13.5
22. Bluestone, 1 to 25, soaked 20 minutes, no rinse	1.5	48	94	26.0	4.0	44	91	14.0
23. Formaldehyde, 1 to 40, smut balls remaining	.4	95	109	23.5	—	—	—	—
24. Formaldehyde, 1 to 40, smut balls skimmed	.2	96	114	22.0				
25. Formaldehyde spray, 0.2 pints to the bushel, covered 4 hours	4.4	48	68	22.5	13.9	42	73	13.0
26. Formaldehyde spray, 0.2 pints to the bushel, covered 24 hours	3.3	42	67	21.5	21.0	33	82	13.5

Rates of sowing as follows

Dry seed, drill at 3½ pecks. Turkey, 60 pounds or 1,246,500 kernels an acre.
Dry seed, drill at 3½ pecks. Fortyfold, 58 pounds or 1,010,600 kernels an acre.
Treated seed, drill at 4½ pecks. Turkey, 53 pounds or 1,084,860 kernels an acre.
Treated seed, drill at 4½ pecks. Fortyfold, 49 pounds or 815,850 kernels an acre.
Sown at once, drill at 4½ pecks. Turkey, 39 pounds or 825,240 kernels an acre.
Sown at once, drill at 4½ pecks. Fortyfold, 34 pounds or 574,980 kernels an acre.

Size of plots, one thirtieth acre. All checks in triplicate, one series on each end and one in the middle. Single plot of all other treatments.

The figures in the preceding tables do not adequately bring out the real difference in the appearance of the treated and untreated plots. Until quite late in the spring there was a marked difference in the appearance of the treated and untreated plots, the latter being much thicker and taller. Fig. 2 shows a general view of the seed-treatment plots in 1919.

Woolman* found that practically all of the loss of germinative power caused by seed treatment with copper sulfate occurs in consequence of injury to the seed coat of the grain, received in threshing, and that seed threshed by hand was uninjured by ordinary treatment with that fungicide. Hurd† confirmed this conclusion and found also that an after-dip in milk of lime was a preventive of injury only to a partial extent depending upon the nature, extent, and location of the breaks in the seed coat. Seed-coat injury is also a factor affecting the germination loss from formaldehyde treatment but to a less extent.

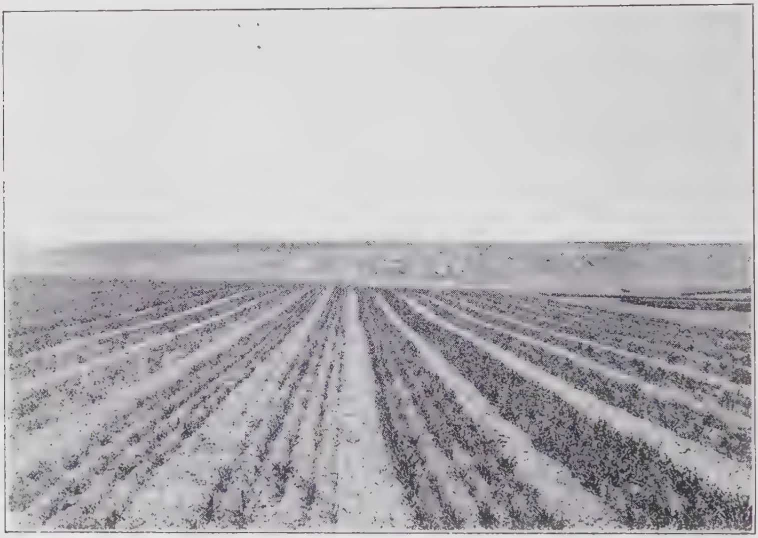

Fig. 2. General view of seed-treatment plots in 1919 showing difference in stands obtained from various seed treatments for smut.
Turkey Fortyfold Turkey Fortyfold
Treated with bluestone, 1 lb. to 10 gallons water, soaked 5 minutes.
No treatment.

In order to determine whether farmers in threshing injure the seed as much as the Station thresher, three samples were obtained from the local warehouse of seed threshed by three different combines, two small outfits, and one large Harris combine. These, with two samples of Station seed, were given four different treatments, as outlined in Table X. Each lot was sown in duplicate two-rod rows with the Planet Junior drill, and a germination test made with 100 kernels of each lot. The germination test was made in a room where the temperature ranged from 30° to 45° F. The results of this germination test are given in Table X.

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* Woolman, H. M. Stinking smut in wheat, Wash. State Exp. Sta. Bul. 73, pp. 8.

†Hurd, Dr. Annie May. Seed-coat injury and viability of seeds of wheat and barley as factors in susceptibility to moulds and fungicides. Jour. Agr. Research V. 21, No. 2, pp. 100-122, plates 13-23.

TABLE X. RESULTS OF GERMINATION TEST BETWEEN BLOTTERS OF FIVE DIFERENT LOTS OF SEED OF TURKEY WHEAT, GIVEN VARIOUS SEED TREATMENTS AT MORO, OREGON

Treatment	Percentage of germination			
	Good	Weak	Dead	Total
	%	%	%	%
Station seed—				
1. Plump (62 pounds per bushel), water soaked 10 minutes	84	14	2	98
2. Plump (62 pounds per bushel), bluestone soaked 5 minutes	16	22	62	38
3. Plump (62 pounds per bushel), formaldehyde 1 to 20, soaked 10 minutes	38	50	12	88
4. Plump (62 pounds per bushel), formaldehyde 1 to 40, soaked 10 minutes	42	40	18	82
1. Shrunken (55 pounds), water soaked 10 minutes	22	76	2	98
2. Shrunken (55 pounds), bluestone soaked 5 minutes	0	22	78	22
3. Shrunken (55 pounds), formaldehyde 1 to 20, 10 minutes soak	10	50	40	60
4. Shrunken (55 pounds), formaldehyde 1 to 40, 10 minutes soak	16	64	20	80
Barnum's seed; plump, small combine (62 pounds)—				
1. Water soaked 10 minutes	82	12	6	94
2. Bluestone 1 to 5, soaked 5 minutes	10	30	60	40
3. Formaldehyde 1 to 20, soaked 10 minutes	40	42	18	82
4. Formaldehyde 1 to 40, soaked 10 minutes	60	28	12	88
Torey's seed; small combine (60 pounds)—				
1. Water soaked 10 minutes	90	10	0	100
2. Bluestone 1 to 5, soaked 5 minutes	14	44	42	58
3. Formaldehyde 1 to 20, soaked 10 minutes	48	52	0	100
4. Formaldehyde 1 to 40, soaked 10 minutes	62	38	0	100
Powell's seed; large combine (59 pounds)—				
1. Water soaked 10 minutes	92	6	2	98
2. Bluestone 1 to 5, soaked 10 minutes	22	32	46	54
3. Formaldehyde 1 to 20, soaked 10 minutes	44	46	10	90
4. Formaldehyde 1 to 40, soaked 10 minutes	70	28	2	98

It will be seen from Table X that considerable injury was done to all the seed, but that the shrunken seed was injured more than the plump seed. It is probable that a large percentage of the seed showing weak germination would never emerge under field conditions.

Table XI gives the results of a test with Turkey, Kanred, and early Baart wheats threshed by hand and by machine. The Turkey wheat was threshed with the Station thresher and the Early Baart with a small combine.

Table XI shows that much more injury occurred to the machine-threshed seed. The germination test was made in a room where freezing temperatures prevailed at night.

TABLE XI. PERCENTAGE OF GERMINATION OF MACHINE- AND HAND-THRESHED SEED OF TURKEY AND EARLY BAART WHEATS TREATED WITH FORMALDEHYDE, 1 TO 24, SOAKED FIVE MINUTES.

Variety	Manner of threshing	Percentage of germination			
		Good	Weak	Dead	Total
		%	%	%	%
Turkey (plump), not treated	Machine	48	42	10	90
Turkey (plump), 1 to 24	Machine	38	42	20	80
Turkey (shrunken), not treated	Machine	18	38	44	56
Turkey (shrunken), 1 to 24	Machine	12	26	62	38
Kanred (plump), not treated	Hand	94	6	0	100
Kanred (plump), 1 to 24	Hand	86	14	0	100
Baart (shrunken), not treated	Hand	80	20	0	100
Baart (shrunken), 1 to 24	Hand	68	30	2	98
Baart (shrunken), not treated	Machine	28	46	26	74
Baart (shrunken), 1 to 24	Machine	8	62	30	70
Baart (plump), not treated	Hand	72	26	2	98
Baart (plump), 1 to 24	Hand	56	28	16	84

Results in 1921. In the fall of 1921, several tests were made to determine the effect on germination, both in the field and in the laboratory, of different wheat varieties given various seed treatments and sown in dry and damp soil.

On September 26, Turkey winter wheat, which had been threshed with the Station thresher, was given five different treatments and sown in damp soil about 2½ inches deep. On October 11, the percentage of germination was as follows:

	Percentage of germination
1. Formaldehyde, 1:44, soaked 5 minutes	80
2. Formaldehyde, 1:44, soaked 5 minutes, rinsed in clear water	100
3. Bluestone, 1:5, rinsed in lime water	66
4. Bluestone, 1:10, rinsed in lime water	93
5. Bluestone, 1:10, not rinsed	78
6. Dry seed, no treatment	93

On September 30, twenty lots of seed including three varieties—Turkey, Hybrid 128, and Blackhull—were given various treatments as indicated in Table XII. Each lot was germinated between blotters in the laboratory and also sown in duplicate series two inches deep in dry soil containing about 5 percent moisture. One series was watered ten days after planting and the other twenty days after planting. The soil was placed in boxes outdoors, and temperatures considerably below freezing prevailed at several different times between date of planting and making final emergence counts. The results obtained are shown in Table XII.

It will be observed from this table that the percentage of germination between blotters in the laboratory and in soil outdoors varied widely in many instances. The formaldehyde-treated seed gave better germination between blotters than in soil, especially when sown in dry soil and not watered for twenty days after planting. Compared with the formaldehyde-treated seed, the bluestone-treated seed gave better germination when sown in dry soil. This was especially true of the seed that remained in dry soil twenty days before the addition of sufficient moisture to begin germination. Averaging all treatments, 16.5 percent more plants emerged from seed treated with bluestone in the first series and 40.5 percent more in the second series than from seed treated with formaldehyde. As is shown in previous tables, the reverse usually occurs at Moro when the seed is sown in damp soil soon after treatment, formaldehyde-treated seed generally giving better stands of wheat.

It will also be noted from Table XII that in every instance both in the laboratory and when planted outdoors in soil, the hand-threshed seed gave much better germination than machine-threshed seed, indicating, beyond question, that seed injury frequently is caused by the threshing machine. The Turkey wheat used in the experiment was obtained from a commercial sample threshed with a large combine. Seed of Hybrid 128 and Blackhull was threshed by the Station thresher. In comparing the machine-threshed with the hand-threshed seed of Hybrid 128 and Blackhull, the average percentage of germination in Series 1 was 77 for the hand-threshed seed as against 40 for machine-threshed seed. In Series 2, the average percentage of germination of these varieties for hand-threshed seed was 68 and for machine-threshed seed, 35.

As is indicated in Table XII, some of the seed was thoroughly dried before sowing and some was sown in the dry soil immediately after treatment or when the seed was damp. The results shown in the table do not indicate any special advantage or disadvantage in sowing dry or damp seed in dry soil. The soil used in this experiment was probably drier than it ordinarily would be under usual field conditions. Dry seed is probably to be preferred in farm practice when seed is sown in soil so dry that prompt germination is not likely to occur.

Table XII also shows the effect of seed treatment in delaying germination. In most instances, the untreated seed emerged sooner than the treated seed. In Series 1, sown in dry soil and watered ten days afterwards, the untreated seed and the formaldehyde-treated seed emerged in most instances sooner than the bluestone-treated seed.

Rinsing the formaldehyde-treated seed in clear water significantly increased the percentage of germination. Rinsing after treatment was much more effective in reducing seed injury than soaking the seed before treatment, as advocated by Braun.*

On November 26, seed of Turkey, Hybrid 128, Hybrid 123 and Triplet were given various treatments with bluestone and formaldehyde, as indicated in Table XIII. The seed was germinated in the laboratory between blotters and sown in damp soil outdoors. The results obtained are shown in Table XIII. In this test again there was a significant difference in the germination of seed threshed by hand and that threshed with a machine. In the use of a solution of formaldehyde as strong as 1 lb. to 20 gallons, it will be noted that considerable injury was done to the seed. This injury, however, was to a considerable extent overcome by rinsing the seed after treatment. The clear water, however, was somewhat more effective in reducing injury than the lime water. In several additional tests carried on at Corvallis and Moro with the formaldehyde-treated seed rinsed in clear water and in lime water, the results showed that clear water was just as efficient in reducing injury as the lime water.

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*Braun, Harry. Presoak method of seed treatment. Journal of Agricultural Research, Vol. XIX, p. 363.

TABLE XII. PERCENTAGE OF GERMINATION OF WINTER WHEAT GIVEN VARIOUS SEED TREATMENTS AND GERMINATED IN LABORATORY AND IN SOIL OUTDOORS

Treatment②	Percentage of germination											
	In laboratory			Series 1①					Series 2①			
	Strong	Weak	Dead	10/28	11/8	11/15	11/28	12/26	11/8	11/15	11/28	12/26
	%	%	%	%	%	%	%	%	%	%	%	%
1A. Dry seed, no treatment	89	9	2	43	79	79	79	82	12	52	60	69
1B. Water soaked 10 minutes, sown damp	89	9	2	40	75	76	77	78	4	48	59	81
2A. Formaldehyde, 1 to 44, sown dry	50	42	8	11	35	39	42	43	3	3	6	15
2B. Formaldehyde, 1 to 44, sown damp	50	42	8	10	40	43	43	45	0	5	6	13
3A. Formaldehyde, 1 to 44, washed clear water, sown dry	86	10	4	23	67	70	70	72	14	56	64	65
3B. Presoak 10 minutes clear water, dry 6 hours, treat as 2A	68	29	3	16	54	55	56	64	1	13	21	21
4A. Bluestone, 1 to 5, rinsed lime water, sown dry	78	15	7	12	65	78	78	78	13	43	54	68
4B. Bluestone, 1 to 5, no lime, sown dry	4	30	66	16	49	56	58	63	4	23	38	54
5A. Bluestone, 1 to 5, limed, sown damp	78	15	7	4	12	25	30	40	10	55	68	81
5B. Bluestone, 1 to 10, no lime, sown damp	40	42	18	4	21	33	38	58	8	52	68	72
6A. Bluestone, 1 to 10, limed, sown dry	62	38	0	4	28	58	64	75	13	82	82	83
6B. Copper carbonate, sown dry	85	14	1	1	12	43	57	65	45	62	72	77
7A. Hybrid 128, machine-threshed, formaldehyde, 1 to 44, sown dry	64	31	5	11	14	22	28	28	0	0	0	2
7B. Hybrid 128, hand-threshed, formaldehyde 1 to 44, sown dry	80	18	2	4	12	15	34	52	1	23	39	45
8A. Blackhull, machine-threshed, formaldehyde, 1 to 44, sown dry	54	35	11	7	19	22	22	24	1	4	7	7
8B. Blackhull, hand-threshed, formaldehyde 1 to 44, sown dry	78	22	0	2	39	71	76	76	37	72	72	76
9A. Hybrid 128, hand-threshed, bluestone, 1 to 5, limed, sown dry	72	28	0	5	14	39	70	95	30	99	99	99
9B. Hybrid 128, machine-threshed, bluestone, 1 to 5, limed, sown dry	4	91	5	0	13	37	52	72	50	64	69	72
10A. Blackhull, hand-threshed, bluestone, 1 to 5, limed, sown dry	90	10	0	8	25	79	86	86	0	35	43	52
10B. Blackhull, machine-threshed, bluestone, 1 to 5, limed, sown dry	35	46	19	0	7	22	30	37	8	37	51	58
Average no treatment	89	....	....	....	....	....	78	80	....	....	60	75
Average, all formaldehyde treatments	66	....	....	....	....	....	46	50.5	....	....	27	30.5
Average, all bluestone treatments	55	....	....	....	....	....	56	67	....	....	64	71
Average, copper carbonate treatment	85	....	....	....	....	....	57	65	....	....	72	77
Average, all hand-threshed	80	....	....	....	....	....	....	77	....	....	....	68
Average, all machine-threshed	39	....	....	....	....	....	....	40	....	....	....	35

① Series 1 sown in dry soil on September 30 and watered October 10.
Series 2 sown in dry soil on September 30 and watered October 20.

② A commercial sample of Turkey wheat threshed with a large combine was used for treatments 1A to 6B, inclusive.

TABLE XIII. PERCENTAGE OF GERMINATION BETWEEN BLOTTERS AND IN SOIL OF FOUR WINTER WHEAT VARIETIES, MACHINE- AND HAND-THRESHED, AND TREATED FOR SMUT WITH FORMALDEHYDE AND BLUESTONE.

Treatment	Germination between blotters			Germination in soil①	
	Strong	Weak	Dead	12-17-21	1-21-22
	%	%	%	%	%
1. Turkey, form. 1 to 20, rinsed clear water	94	5	1	19	42
2. Turkey, form. 1 to 20, rinsed lime water	52	30	18	12	48
3. Turkey, not treated, dry seed	76	22	2	6	46
4. Turkey, hand-threshed, form. 1 to 20	50	50	0	38	73
5. Turkey, hand-threshed, $CuSO_4$, 1 to 5, limed	90	10	0	55	67
6. Turkey, machine-threshed, form. 1 to 20	78	18	4	3	17
7. Turkey, machine-threshed, $CuSO_4$, 1 to 20, limed	40	52	8	14	26
8. Hybrid 128, hand-threshed, form. 1 to 20	84	16	0	15	16
9. Hybrid 128, hand-threshed, $CuSO_4$, 1 to 5, limed	94	6	0	17	33
10. Hybrid 128, machine-threshed, form. 1 to 20	34	50	16	5	9
11. Hybrid 128, mach-threshed, $CuSO_4$, 1 to 5, limed	22	74	4	9	16
12. Hybrid 123, hand-threshed, form. 1 to 20	98	2	0	41	29
13. Hybrid 123, hand-threshed, $CuSO_4$, 1 to 5, limed	94	6	0	37	48
14. Hybrid 123, machine-threshed, form. 1 to 20	66	26	8	4	5
15. Hybrid 123, mach-threshed, $CuSO_4$, 1 to 5, limed	60	32	8	8	13
16. Triplet, hand-threshed, form. 1 to 20	82	16	2	16	53
17. Triplet, hand-threshed, $CuSO_4$, 1 to 5, limed	90	10	0	34	53
18. Triplet, machine-threshed, form. 1 to 20	74	26	0	16	33
19. Triplet, machine-threshed, $CuSO_4$, 1 to 5, limed	50	40	10	3	23

①On account of cold weather, complete emergence had not taken place.

WHY SEED IS INJURED BY TREATMENT WITH FUNGICIDES

The failure of seed to germinate after treatment with formaldehyde appears to depend largely on the length of time intervening between treatment and planting, and upon the conditions under which it is kept or stored. In the case of immediate planting, the degree of soil moisture is also an important factor.

Without doubt the factor of greatest importance in causing loss of seed in treating is the injury sustained by the seed coat in threshing. As has been stated, this factor is of more importance in treatment with bluestone than with formaldehyde. The nature of this injury to the seed coat is clearly shown in Fig. 3, *A* and *B*. The apparent difference in size between the uninjured hand-threshed seed and the machine-threshed is due to the fact that the first was untreated while the second had been treated by various methods. It will be noted that there is some difference in the character of the injury in the soft, plump-kerneled White Winter wheat grown at Corvallis and the hard, shrunken, long-kerneled Turkey wheat grown at Moro, in that the injury to the latter is more nearly confined to the seed coat over the germ. It is probable that some varieties are more easily injured than others, but this has not been definitely proved. It is, however, true beyond doubt that grain threshed under very dry conditions is injured more than when the grain is slightly moist or the atmosphere humid.

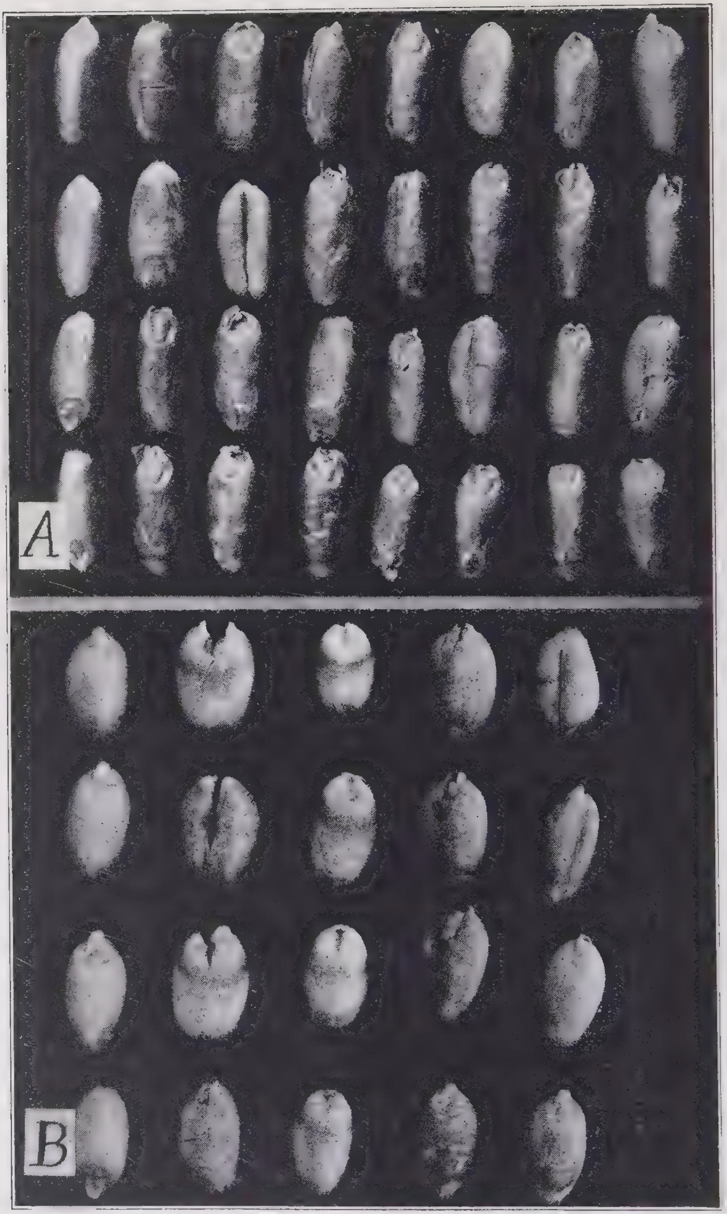

Fig 3. Threshing injury. *A*. Turkey Red from Moro. *B*. White Winter from Corvallis. Hand-threshed on left. Machine-threshed on right.

Falke* found that wheat produced in a dry year was injured more in treating with bluestone than that produced in an ordinary year. He believed that this held good even if the seed coat was unbroken, but the data he presents do not prove this contention.

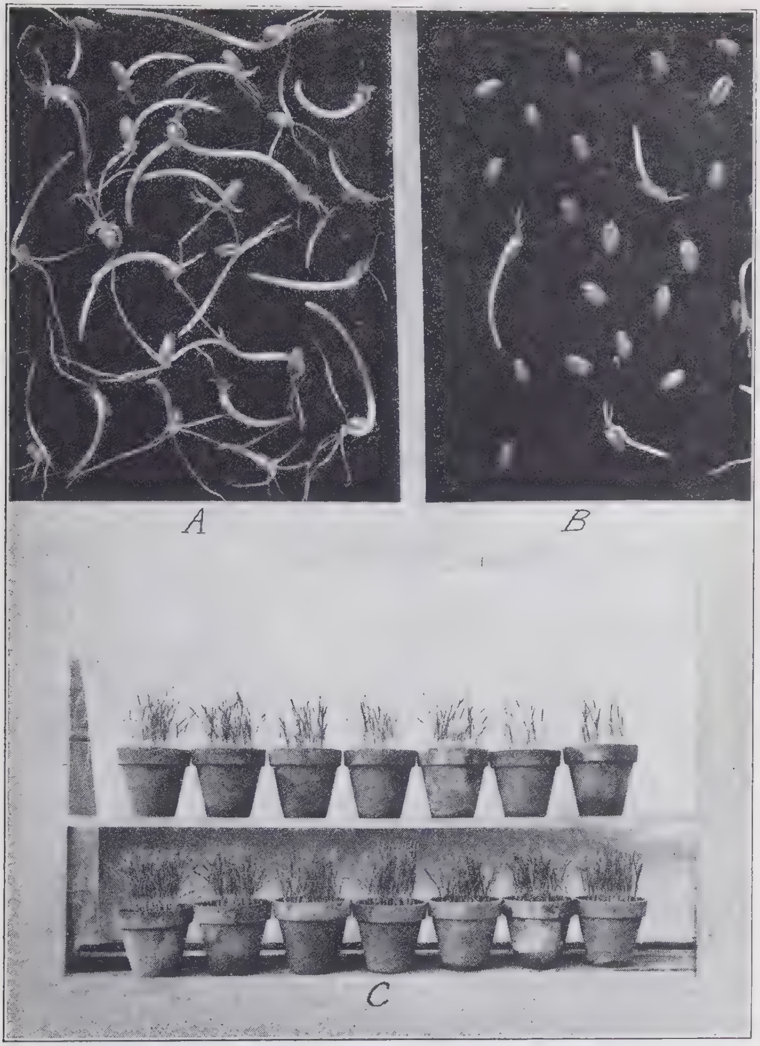

Fig. 4. Hand- and machine-threshed seed, treated with copper sulfate 1 pound to 5 gallons. Explanation in text.

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*Falke, Fr. 1905. Beobachtungen uber den Einfiuss der Saatgutbeize auf die Keimfahigkeit des Getreides in trockenen Jahren (1904.) Observations concerning the influence of seed treatment upon the germinative power of cereals in dry years. In Illus. Landw. Ztg., Jahrg, 25 No. 53, p. 479-480, 1905.

Certain interesting facts concerning treatment injury to hand- and machine-threshed seed are shown in Fig. 4. *A* shows 25 grains of Fortyfold wheat selected at random from a lot of hand-threshed seed that had been treated for five minutes with a bluestone solution of 1 pound to 5 gallons of water germinated between moist blotting paper; *B* shows the same except that it was machine-threshed. *C* shows pot cultures of the same seed lots with the same solution as *A* and *B* for varying lengths of

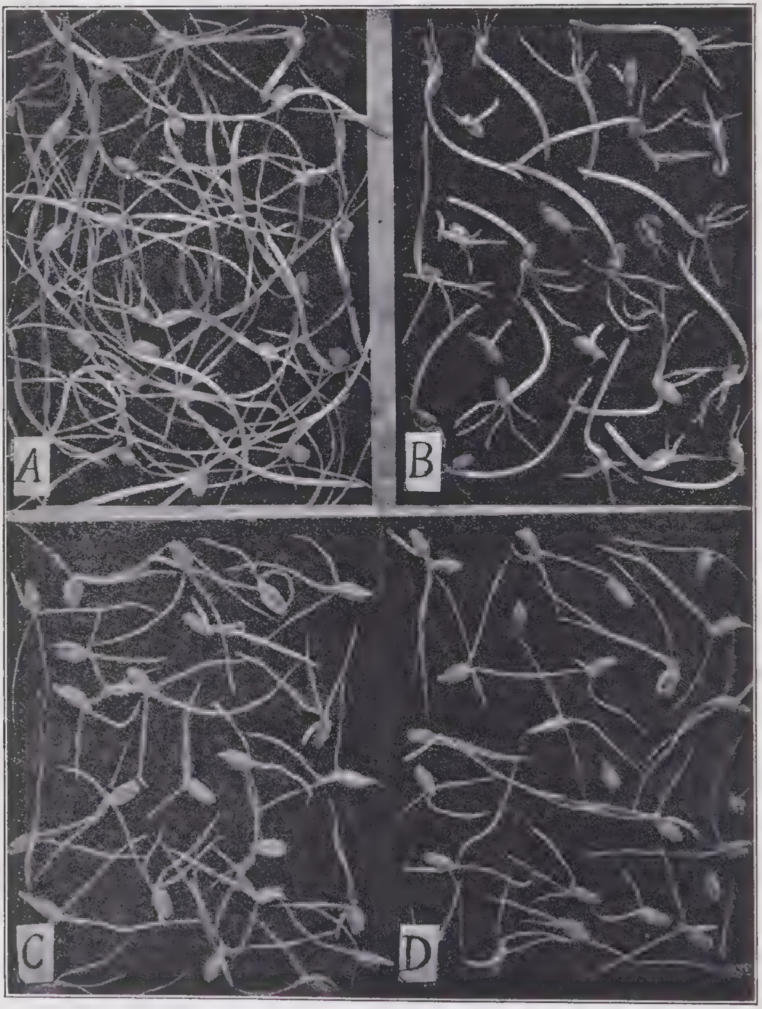

Fig. 5. *A*. Hand-threshed, no treatment. *B*. Machine-threshed, no treatment. *C*. Hand-threshed, treated in 1 to 40 formaldehyde 30 minutes. *D*. Machine-threshed, same treatment as *C*.

time. Upper row was machine-threshed, lower row hand-threshed. Counting from the left, the second lower pot was planted with 25 grains of the same lot as *A*. Second upper from same lot as *B*. Judging from *B*, one would suppose that 80 percent of the grains were dead, but when planted in soil they gave nearly 80 percent of plants. This is unquestionably due to the action of certain chemical substances in the soil that counteract the toxic effects of the bluestone on the grain.

The length of treatment in the pot series is, left to right: 1, no treatment; 2, 5 min.; 3, 10 min.; 4, 30 min.; 5, 1 hour; 6, 5 hours; 7, 10 hours.

In Fig. 5, *A* is hand-threshed, no treatment; *B*, machine-threshed, no treatment; *C*, hand-threshed, 30 minutes in formaldehyde, 1 pint to 40 gallons; and *D*, machine-threshed, same treatment as *C*.

A and *B* show that there is some loss and delayed growth in untreated seed due to threshing injury. Several of the grains shown in *B* would never have emerged if planted under ordinary field conditions. In Fig. 5, *C* and *D* show to some extent the nature of formaldehyde injury. For this short treatment (30 minutes) but little difference between hand- and machine-threshed seed is apparent. One action of formaldehyde on all wheat is the hardening of the seed coat which makes it difficult for the plumule to break through, causing it sometimes to break out at the brush end of the seed. It also causes crooked and distorted plumules which never reach the surface. This explains why blotter germination tests do not fully indicate the actual damage done by formaldehyde. The opposite is true in the case of copper-sulfate treatment, where the stand in the field is generally better than blotter tests indicate. Delayed germination in formaldehyde-treated grain is clearly shown in the figures, as all blotter germinations shown in Figs. 3 and 4 are of the same age.

Considerable light is thrown on the reasons why chemical treatment is injurious to the vitality of the seed, at least in so far as formaldehyde is concerned, by the studies carried on in 1919, 1920 and 1921 by Dr. W. M. Atwood, Plant Physiologist of the Oregon Agricultural College Experiment Station. In the course of work now ready for publication he found: (1) that formaldehyde is able slowly to penetrate the seed coats in aqueous solution, the coats acting as a partly permeable membrane to formaldehyde; (2) that it lowers diastatic enzyme activity; (3) that it checks the respiratory activity of the seed; and (4) that it reduces the catalase content of the seed in proportion to the concentration of the formaldehyde solution used.

These effects all retard important normal functions involved in healthy seed germination, although the actual results are not severe in the case of uninjured seed where the standard dilution of formaldehyde is used and germination is started promptly.

Breaks in the seed coat promote another class of losses not necessarily related to treatment, in that they facilitate the attack of molds and other soil fungi which rob the young plant of the food supply stored in the seed, and upon which it is dependent until it emerges from the soil. The relation of seed treatment to this trouble has not been fully investigated. According to Hurd* treatment with copper sulfate under some circumstances delays the attack of these fungi, but formaldehyde treatment is likely to promote the attack. German investigators have expressed the same opinion.

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* Hurd, Dr. Annie May. Seed-coat injury, etc. Jour. of Agr. Research, Vol. XXI, No. 2, pp. 99-122.

During 1918, 1919, and 1920, an extensive series of tests to determine the relative merits of various seed treatments for the prevention of bunt in relation to loss of germinative power were carried out at Corvallis by Miss Jessie P. Rose, for the Office of Cereal Investigation, in cooperation with the Oregon Experiment Station. Many hundreds of individual tests were made, involving a record of the germination of half a million wheat kernels of eighteen varieties, laboratory, greenhouse, and field. It is to be hoped that the results of this work will soon be published in full. In the meantime, certain important conclusions will be stated here.

Of the treatments experimented with, thirteen involved the use of copper sulfate (bluestone), thirty formaldehyde, three hot water, three calcium hypochlorite, and several mercuric chloride (corrosive sublimate). Of all those tested, the two following gave the best results in percentage of seedlings obtained and in total yield of wheat: (1) Dip (ten minutes) in a solution of one pound of copper sulfate to five gallons of water; drain fifteen minutes, and then dip five minutes in milk of lime, one pound of lime to ten gallons of water. (2) Three-minute dip in a solution of one pint of 37 percent commercial formaldehyde to three hundred twenty pints (forty gallons) of water; then cover for four hours.

Turkey wheat when treated by the first, or bluestone-lime method, gave an average increase of 18 percent of plants and 10 percent in yield of wheat over that obtained when the second or formaldehyde method, was used. Other varieties gave similar results.

Miss Rose's conclusions regarding the relation of threshing injury to treatment loss is in agreement with those of other investigators. For example, in one of her tests hand-threshed Turkey Red gave not only better germination, but also 59 percent greater yield of grain than machine-threshed seed. In Marquis there was a 16-percent gain.

Miss Rose found that uninjured wheat when treated by the bluestone-lime method and thoroughly dried, could be stored for two years with but little loss of germination power, and that the addition of salt to bluestone solutions somewhat increased the loss, the degree of injury being proportionate to the amount of salt used.

The general results of Miss Rose's experiments, as well as those of C. W. Hungerford assisted in part by J. T. Bregger, at Corvallis, confirm the general conclusions arrived at from the Moro experiments, although under the soil and climatic conditions of the Willamette Valley the extent of injury was not always as great as at Moro.

CONCLUSIONS DRAWN FROM EXPERIMENTS HEREIN DESCRIBED, AND THOSE OF OTHER INVESTIGATORS.

All investigators are practically agreed on the following points in regard to treatment of wheat with formaldehyde solutions:

(1) If the time of immersion and subsequent covering does not exceed four hours and the seed is sown soon after treatment, or while the seed is moist, in soil with enough moisture to cause immediate germination and uninterrupted growth, but little injury results.

(2) Sowing damp seed in dry soil is not advisable.

(3) Treated seed kept damp will not suffer further injury for several days, unless it heats or is attacked by molds. It is believed by some that the treated seed can be dried at comparatively high temperatures in atmosphere of the right humidity, and then stored dry for an indefinite time without greater loss than would have been sustained if it had been sown damp. The results of drying and storing formaldehyde-treated seed are, however, so dependent on atmospheric conditions and temperature and require such expert care that it is a hazardous process at best, and should be avoided when possible, unless the seed is washed in water immediately after the covering period.

Probably all persons who have used formaldehyde have observed a white, flocculent precipitate which forms in a bottle that has been standing for some time, and which readily dissolves when the liquid is warmed. This is known as paraformaldehyde, a very poisonous substance. Working in California, Hurd* found that the formation of this substance on the surface of formaldehyde-treated seed when it was dried after treatment was the cause of a larger part of the seed loss in dry storage. She proved by experiment that washing in water before drying prevented the formation of this injurious substance and removed the danger of after-treatment injury. It should be noted, however, that a certain amount of injury takes place during the treatment that no subsequent bath will obviate. Experiments at Corvallis and at Moro in the fall of 1921 show that a pure-water wash after formaldehyde was equally as effective in reducing seed injury as a wash in lime water.

It has been found that in farm practice too little attention is ordinarily paid to the strength of the bluestone solution used in treating seed. Soaking seed for five minutes in a solution of 1 lb. of bluestone to 5 to 10 gallons of water will ordinarily control bunt except in cases of bunt-infested soil. To lessen seed injury, an after-dip in lime water of the strength of 1 lb. of ordinary slaked lime to 10 gallons of water is always advisable.

The bluestone treatment is always to be preferred if the seed is to be stored for any length of time before sowing or if the seed is to be sown in dry ground.

For controlling bunt, a solution of formaldehyde stronger than 1 pint of commercial formaldehyde to 40 gallons of water is not necessary. One pint to 45 gallons with a five-minute soak has been found in farm practice to control stinking smut effectively where the soil is not contaminated with smut spores.

Treating seeds with bluestone or copper sulfate is a safer farm practice when the seed is sown in ground with insufficient moisture to start germination immediately, and maintain continuous growth.

The addition of common salt to a bluestone solution appears to increase its fungicidal properties but also causes slightly more seed injury. In most localities in Oregon, addition of salt is not necessary to control bunt.

During the past 30 years, chemists and other investigators have spent many days in the quest of a fungicide that would be efficient against the smuts and at the same time non-injurious to the seed. None has yet been found that meets both these conditions perfectly, unless the new method, now under trial, of treating with dry, powdered copper carbonate should prove to be the long-sought method. Darnell-Smith* after three years of trial in Australia reported the copper-carbonate treatment non-injurious to the seed and effectual against bunt. Professor W. W. Mackie of the University of California has made many trials and is favorably impressed with its results. Experimental work with this fungicide in Oregon is in progress and sufficient data are now available to prove that the copper-carbonate treatment causes little, if any, injury to the seed. In a field test near Corvallis seed treated by this method produced a stand fully equal to the untreated seed. Another season's results will be required to determine definitely whether this treatment will effectively control bunt under conditions prevailing in Oregon.

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* Hurd, Dr. Annie May. Injury to seed wheat resulting from drying after disinfection with formaldehyde. Jour. Agr. Research, Vol. 20, No. 3, pp. 209-244, plates 36-41.

II. BUNT-RESISTANT WHEAT VARIETIES

Varieties of wheat vary greatly in their susceptibility to stinking smut. Some varieties are exceedingly resistant, while others are very susceptible to this disease. Of the commercial varieties of wheat now grown in Oregon, not one is sufficiently resistant to the disease to permit treatment of the seed to be dispensed with. If there can be developed high-yielding varieties sufficiently resistant to stinking smut so that untreated seed could be sown with an assurance of a comparatively smut-free crop, it would result in the saving of hundreds of thousands of dollars annually to the farmers of the State.

Of the wheat varieties grown commercially in Oregon, those of the Crimean group, such as Turkey, Kharkov, and Kanred, are the most smut-resistant, though none of these is sufficiently resistant to be safely sown without seed treatment.

In 1917 preliminary work in cooperation with the Office of Cereal Investigations of the United States Department of Agriculture was started at the Sherman County Branch Experiment Station and at Corvallis to determine the comparative smut resistance of wheat varieties. During the year 1917, Mr. F. J. Schneiderhan was in direct charge of the cereal breeding work at Moro.

In the fall of that year thirteen varieties of wheat were sown at Moro and Corvallis under the direction of Mr. C. W. Hungerford. At Corvallis the plantings were in plots of four one-rod rows replicated three times. Both soil and seed were artificially and heavily infested with spores of *T. tritici*. At Moro only one one-rod row was planted in infested soil and three one-rod rows with the seed only infested.

The results are given in Table XV.

In the fall of 1918 this work was elaborated on a rather large scale. All of the commercial wheats of the United States, assembled by Messrs. Ball and Clark and grown in the classification nursery at Moro, were sown in rod rows with heavily smutted seed. In this trial were 455 varieties or pure-line selections. These varieties were also all sown with smutted seed in the autumn of 1919. Two years' data, therefore, are available on the comparative smut resistance of all the commercial wheat varieties of the

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* Darnell-Smith. A dry method of treating seed wheat for bunt. Agr. Gaz. N. S. Wales V. 30, part 10, pp. 685-692.

TABLE XV. RESULTS OF VARIETY TESTS FOR BUNT RESISTANCE IN PERCENTAGE OF BUNTED HEADS FOR THE SEASON OF 1917-18 AT CORVALLIS AND MORO, OREGON.

Variety	Corvallis	Moro		Average
	Soil and seed infested	Soil and seed infested	Seed only infested	
	%	%	%	%
Eaton	79	74	79	77.3
Foisy	84	75	70	76.3
Fortyfold	71	88.5	70	76.5
Golden Cross	62	76	64	67.3
Jones Fife	71	87	61	73.0
Kinney	72	84	80	78.7
Little Club	81	80	72	77.7
Queen Wilhilmina	67	66	61	64.7
Red Russian	37	72	68	59.0
Titanic	6.3	6	1.6	2.8
Turkey, C. I. 1558	47	18	17	27.3
Hybrid 128	62	74	54	63.3
White Winter	79.5	83	74	78.8

United States. There were also sown in the fall of 1918, 134 two-rod rows of pure-line selections from Crimean wheats that had been previously made by Mr. Schneiderhan at the Branch Station at Moro and were being tested for yield. Many of these selections had been grown for several years without seed treatment and contained no smut. It was thought, therefore, that some of them might prove to be more resistant to this disease than the common Crimean varieties.

In the spring of 1919, the commercial wheat varieties of Australia, comprising 85 varieties, and the commercial wheats of India, comprising 120 varieties, were sown in two-rod rows with artificially smutted seed. These wheats had previously been obtained by the United States Department of Agriculture from these countries for experimental purposes.

In Table XVI are listed most of the common wheat varieties grown in the Northwest and other commercial wheat varieties of the United States which contained the least smut in the 1919 and 1920 crops. The percentage of smut in each variety is based on the number of smutted heads in comparison with the total number of heads in a rod row. A complete list of the varieties tested for smut is not included in this bulletin.

TABLE XVI. LIST OF WINTER WHEAT VARIETIES GROWN AT MORO, OREGON, IN 1919 AND 1920, FROM ARTIFICIALLY INFESTED SEED, SHOWING PERCENTAGE OF SMUT INFECTION IN RESULTING PLANTS

Variety	C. I. No.	Percentage of smutted plants in		
		1919	1920	Average
		%	%	%
Martin (Martin Amber)	4463	00	00	00
Martin (Martin Amber)	4636	90	77	83
Prohibition	4068	96	97	96
White Winter	4684	34	81	57
White Winter	5219	75	93	84
White Winter	5224	39	94	66
Challenge (Webb Challenge White)	4683	37	75	56
Challenge (Webb Challenge White)	4684-B	15	91	53
Challenge (Webb Challenge White)	5227-B	87	87	87
Eaton	4362	42	84	63
Eaton	4682	96	82	89
Eaton	5219-B	24	90	57
Defiance	4347	97	83	90
Defiance	4354	71	①	...
Defiance	4764	65	①	....
Rink	5866	96	91	93
Rink	5867	96	68	82
Rink	5868	58	91	74
Gypsum (Colorado Special)	4761	71	①	...
Gypsum (Colorado Special)	4762	78	91	84
Gypsum (Colorado Special)	4928	15	90	52
Pacific Bluestem	4067	28	94	61
Pacific Bluestem	4606	51	65	58
Pacific Bluestem (White Australian)	3019	52	46	49
White Track	5230	94	81	87
White Track	5231	80	65	72
White Track	5267	85	92	88
Dicklow	3663	75	①	....
Dicklow	5285	99	①	....
Dicklow	5898	76	①	.
Surprise (California Gem)	2986	85	①	....
Surprise (California Gem)	4248	76	①	
Surprise (White Russian)	5277	71	①	....
Bobs	4990	69	50	59
White Fife	4412	53	34	43
White Fife	4955	35	50	42
Regenerated Defiance	3703	50	①	....
Regenerated Defiance	4763	50	①	....
Regenerated Defiance	5265	53	81	67
Lofthouse	3275	78	76	77
Lofthouse	5875	95	84	89
Red Russian	4509	83	90	86
Red Russian	4681	83	80	81
Kinney	5189	95	94	94
Kinney	5192	55	90	72
Kinney	5195	80	81	80
Huston	5208	60	70	65
Huston	5209	71	73	72
Marquis	3641	32	40	36
Marquis	5954	75	45	60
Marquis	5294	67	34	50
Kofod	2997	60	75	67
Kofod	4337	0.3	25	12
Kofod	4339	00	7.7	3
White Odessa	4480	78	66	72
White Odessa	4651	1	00	0.5
White Odessa	4655	4	0.7	2
Foisy	5242	83	94	88
Foisy	5246	71	80	79
Foisy (Oregon Goldenchaff)	5283	82	60	75
Arcadian (Early Arcadian)	3390	97	70	83

①Winter killed.

TABLE XVI.—(Continued)

Variety	C. I. No.	Percentage of smutted plants in		
		1919	1920	Average
		%	%	%
Arcadian (Early Arcadian)	4220	85	75	80
Arcadian (Early Arcadian)	5871	88	70	79
Goldcoin (Fortyfold)	2996	87	67	77
Goldcoin (Fortyfold)	4230	80	60	70
Goldcoin (Fortyfold)	4500	39	72	55
Allen (Red Allen)	5407	11	①	....
Federation	4609	30	①	...
Hard Federation	4980	62	50	56
Odessa	3003	93	94	93
Odessa	3274	51	85	68
Odessa	4475	56	57	56
Jumbuck	4608	8	76	42
Triplet	5408	91	80	85
Jones Fife	4468	77	51	64
Jones Fife	5236	78	66	72
Jones Fife (Crail Fife)	4162	84	91	87
Jones Fife (Super)	5544	75	86	80
Galgalos	2398	49	56	52
Galgalos	4467	24	60	42
Sonora	3036	56	①	....
Sonora	4293	98	①	...
Sonora	4501	52	①	....
Baart (Early Baart)	1697	32	100	66
Baart (Early Baart)	4206	18	73	45
Saumur	2346	23	45	34
Talimka	2945	27	45	38
Hussar (Red Hussar)	4843	00	00	00
Kharkov	1442	5	.06	2
Turkey	1558	9	.08	4
Beloglina	1543	25	30	27
Beloglina	1667	13	20	16
Beloglina	2239.	90	60	75
Kanred	5146	00	11	5
Prelude	4323	72	①	....
Hybrid 60	5024	99	92	95
Hybrid 128	4229	82	93	87
Hybrid 128	4257	29	94	61
Hybrid 128	4512	88	95	91
Little Club	4066	50	90	70
Little Club	4225	73	100	86
Little Club	5897	78	87	82
Big Club	4209	63	96	79
Big Club	4257	44	50	47
Big Club (Salt Lake Club)	3018	50	①	....
Hybrid 63	4157	95	95	95
Hybrid 63	4252	78	100	89
Hybrid 63	4510	90	95	92
Hybrid 143	4160	95	100	97
Hybrid 143	4513	87	96	91
Hybrid 143	5255	94	90	92
Washington No. 3	4239	3	16	9
Washington No. 3	4669	13	20	16
Hybrid 108	5025	82	66	74
Hybrid 123	4511	91	60	75
Jenkin	5177	46	①	....
Jenkin	5261	85	①	...
Jenkin	5903	51	①	....
Redchaff	4241	60	①	....
Redchaff	4243	58	①	....
Redchaff	4250	41	①	....
Bluechaff	5178	68	①	...
Bluechaff	5256	23	99	61
Bluechaff	5257	42	96	69
Dale (Dale Gloria)	4155	51	①	....
Dale (Dale Gloria)	4255	54	①	....
Dale (Dale Gloria)	5902-A	68	①	.
Coppei	3088	75	60	67
Coppei	4238	73	50	61
Mayview	5874	74	①	....

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① Winter killed.

The Pure-Line Crimean Wheats. Of the pure-line Crimean wheats, the varieties listed in Table XVII were the ones that showed least smut infection. The percentage of smut is based on the number of smutted heads compared with the total number of heads in a two-rod row. The total number of heads in each row varied from 420 to 1175.

TABLE XVII. PURE-LINE SELECTIONS FROM CRIMEAN WHEATS GROWN AT MORO, OREGON, IN 1919 SHOWING PERCENTAGE OF SMUT IN PLANTS FROM ARTIFICIALLY INFESTED SEED.

Original name	C. I. No. and selection designation	Percent smut
Turkey	P–704 ①	7.0
Kharkov	1442–B	3.2
	1532	2.3
Turkey	1558–A	2.8
Turkey	1558–3–09	9.6
Weissenberg	1563–2	5.2
Polish	1565–1	2.8
Turkey	1571–C	6.5
Girgeh	1580–11	7.5
Servian	1728–1–4–1–10	5.9
Diminum	2191–1	5.5
	2576-A	3.6
Rietti	2578-1	0.54
Mediterranean	2903-5	2.3
Molakof	2908–A	1.8
Turkey	3055–A	1.0
	44 30	3.6

① Pedigree number of the Botany department of the Kansas Agricultural Experiment Station.

Australian and Indian Wheat Varieties. Of the 85 Australian wheat varieties, the following contained the least smut:

Variety	C. I. number	Percent smut
Nardoo	4985	10
Cowra No. 16	4738	14
Florence	4170	16

Of the Indian wheats there was not one of the 120 varieties that showed any resistance to this disease.

The outstanding feature of the 1919 harvest was the discovery of the immune or highly resistant character of Red Hussar, C. I. 4843, Martin Amber, C. I. 4463 and White Odessa, C. I. 4651 and 4655. The first two have never yet shown a trace of bunt, while the two White Odessa strains have averaged less than 1 percent of bunted heads. Red Hussar is a hard, red-bearded wheat, while Martin Amber and the White Odessas are soft, white, and beardless.

Results for 1919-20. In the fall of 1919, the classification nursery list was again planted at Moro, and in addition the most promising bunt-resistant varieties were planted at Corvallis, Moro, Hermiston, and Union. Several strains of Florence x Turkey and Hybrid 128 x Turkey, produced by Dr. E. F. Gaines of the Washington Agricultural Experiment Station at Pullman, were sent to us by him. Some of these give promise of being valuable resistant wheats.

The results of this year's work are summarized in Table XVIII.

TABLE XVIII. PERCENTAGE OF SMUT IN WINTER WHEAT VARIETIES GROWN AT MORO, CORVALLIS, HERMISTON, AND UNION, OREGON, IN 1920, FROM ARTIFICIALLY INFESTED SEED

Variety	C. I. No.	Percentage of smutted heads at				
		Corvallis	Moro	Hermiston	Union	Average
		%	%	%	%	%
Hybrid 143	4513	70.8	68.0	60.3	15.4	53.6
Turkey	....	20.5	14.6	19.6	6.6	15.3
"Banner Berkeley'	....	1.8	0.6	0.0	0.0	0.6
Medeah	....	0.0	....	....	....	0.0
Red Hussar	4843	0.0	0.0	0.0	0.0	0.0
Red Allen	5407	30.6	....	....	....	30.6
Alaska x Jones Fife	6682	10.6	2.8	0.0	1.3	3.7
Kharkov	1442	24.5	4.7	0.0	2.7	8.0
Kharkov	1442–12	26.6	18.9	4.5	2.5	13.1
Turkey (Wn. No. 326)	6175	28.0	2.7	1.4	1.2	8.3
Turkey	1558	14.8	10.6	0.0	1.8	6.8
Kofod	4337	7.2	24.2	....	....	15.7
Kofod	4339	6.4	7.7	....	....	7.05
Washington No. 3	4669	6.7	1.5	....	0.0	2.7
Washington No. 3	4239	74.5	16.2	....	4.8	31.8
Florence	....	4.9	2.6	....	0.0	2.5
White Odessa	4651	0.0	0.0	0.0	0.0	0.0
White Odessa	4655	2.1	0.7	....	0.0	0.9
Martin	4463	....	0.0	....	....	0.0
Crimean selections	2191–1	0.0	0.6	0.0	0.2	0.2
	1558-A	0.0	1.8	2.4	0.0	1.05
	1558–B	0.9	0.0	0.0	0.3	0.3
	1558–11	20.5	1.5	0.0	0.8	5.7
	1558–3–09	20.3	1.4	0.0	0.3	5.5
	4430	0.6	0.5	0.0	0.0	0.3
	2576–A	0.4	0.0	0.0	0.0	0.1
	1442–15–09	23.2	2.7	0.0	0.0	6.5
	2578–1	0.5	0.0	0.0	1.3	0.45
	2908-A	11.2	0.8	0.0	0.0	3.0
	3055-A	0.0	0.0	0.0	0.0	0.0
	1728–1–4–1–10	12.8	1.1	2.6	0.8	4.3
	1563–2	7.1	2.0	0.0	0.0	2.3
	1571-C	0.6	1.0	1.6	0.0	0.8
	2903–5	0.0	0.0	0.0	1.0	0.25
	1565–1	0.8	2.3	3.6	0.0	1.7
	1532	0.2	0.4	3.3	0.0	1.0
P-704	....	31.5	3.1	2.4	1.0	9.5
Turk. x Hyb. 128 (G 176)	....	23.0	11.2	16.0	5.1	13.8
Turk. x Hyb. 128 (G 238)	....	46.1	8.2	11.0	2.0	16.8
Turk. x Hyb. 128 (G 242)	....	22.6	13.7	17.9	5.8	15.0
Turk. x Hyb. 128 (G 247)	....	44.6	10.6	6.0	2.9	16.0
Turk. x Hyb. 128 (G 308)	....	33.9	10.6	13.8	3.5	15.45
Turk. x Hyb. 128 (G 311)	....	50.2	15.6	22.7	9.8	24.6
Turk. x Florence (G 314)	....	2.3	1.6	1.9	0.8	1.65
Turk. x Florence (G 316)	....	2.4	0.0	0.0	0.3	0.7
Turk. x Florence (G 324)	....	1.1	0.0	0.7	0.0	0.45
Turk. x Florence (G 326)	....	0.0	trace	0.0	0.0	0.0
Turk. x Florence (G 330)	....	0.5	0.0	0.0	0.0	0.1
Turk. x Florence (G 332)	....	0.7	1.1	0.9	0.0	0.7
Turk. x Florence (G 334)	....	2.8	1.0	trace	0.0	0.95
Tur. x Fl. (G 352) (brded)	....	3.6	0.5	3.5	0.0	1.9
Tur. x Fl. (G 352) (brdl's)	....	4.9	1.3	3.3	0.0	2.4

Results in 1921. In the autumn of 1920 there were sown at Moro and at Corvallis with artificially smutted seed in two-rod rows those varieties which had previously showed some resistance to stinking smut and a few standard varieties for comparison. There were also included three varieties, Blackhull, Alberta Red, C. I. No. 5971, and bulk seed of Red Hussar obtained from the Illinois Agricultural Experiment Station. The percentage of smut obtained in the 1921 crop of each variety grown at Moro and at Corvallis is given in Table XIX, with the average percentage for both places.

TABLE XIX. PERCENTAGE OF SMUT IN WINTER WHEAT VARIETIES GROWN AT MORO, AND CORVALLIS, OREGON, IN 1921.

Variety	C. I. No.	Percentage of smutted heads at		
		Moro	Corvallis	Average
		%	%	%
Hybrid 143		43.0	82.0	62.0
Banner Berkeley		0.6	0.5	0.5
Martin		0.0	0.0	0.0
Red Hussar		0.0	0.0	0.0
Alaska x Jones Fife		2.5	13.0	7.7
Turkey (Washington No. 326)		3.1	18.0	10.5
Kofod	4337	2.4	29.0	16.0
Kofod	4339	1.6	13.0	7.3
Washington No. 3	4669	6.0	10.0	8.0
Washington No. 3	4239	10.0	58.0	34.0
Florence		2.2	11.0	6.6
White Odessa	4651	0.2	0.0	0.1
White Odessa	4655	0.0	0.0	0.0
Kanred	5146	6.0	11.0	8.0
Turkey (889)		4.0	8.7	6.3
Crimean selections	1558-A	3.2	0.4	1.8
	1558-B	1.1	0.9	1.0
	2191-1	1.5	0.0	0.7
	4430	0.2	0.0	0.1
	2576-A	2.0	0.8	1.4
	1532	5.9	2.8	4.3
	2578-1	1.6	1.4	1.5
	2908-A	0.7	5.8	3.2
	3055-A	0.3	0.3	0.3
	1728-1-4-1-10	3.0	5.2	4.1
	1563-2	0.3	1.4	0.8
	1571-C	1.0	0.0	0.5
	2903-5	0.6	0.0	0.3
	1565-1	2.8	5.6	4.2
Turkey x Hyb. 128 (G 176)		4.3	29.0	16.0
Turkey x Hybrid 128 (G 238)		4.2	42.0	23.0
Turkey x Hybrid 128 (G 242)		2.3	60.0	31.0
Turkey x Hybrid 128 (G 247)		6.0	39.0	22.0
Washington No. 13001		10.0	35.0	22.0
Hybrid 128		70.0	55.0	62.0
Turkey x Florence (G 314 Red)		0.0	0.0	0.0
Turk. x Florence (G 314 White)		0.3	0.0	0.1
Turkey x Florence (G 316)		0.1	0.0	.05
Turkey x Florence (G 324)		0.0	0.8	0.4
Turkey x Florence (G 326 Red)		0.2	0.0	0.1
Turk. x Florence (G 326 White)		0.0	0.0	0.0
Turkey x Florence (G 330)		0.2	0.82	0.5
Turkey x Florence (G 332)		0.0	4.82	2.4
Turkey x Florence (G 334)		0.0	1.84	0.9
Blackhull		44.0		
Alberta Red	5971	12.0		
Red Hussar (Bulk seed)①		10.0		

① Seed from Illinois Agricultural Experiment Station.

Yields of Smut-Resistant Varieties. Comparative yields of the smut-resistant varieties were obtained in 1920 and 1921 in two-rod nursery rows replicated from three to five times. The annual and average yields are reported in Table XX, together with the yields of a pure line of Kharkov winter wheat, C. I. 1442-12. These wheats will be further tested in larger plots to determine which are the highest yielding varieties.

TABLE XX. ANNUAL AND AVERAGE ACRE YIELDS, IN BUSHELS, OF SMUT-RESISTANT WHEAT VARIETIES GROWN IN NURSERY ROWS AT MORO, OREGON, IN 1920 AND 1921

Variety	C. I. No.	Acre yield		
		1920	1921	Average
		bu.	bu.	bu.
Crimean selection	1532	21.7	33.5	27.6
Crimean selection	1558-A	32.5	30.2	31.3
Crimean selection	1558-B	23.3	29.7	26.5
Crimean selection	1565	14.6	20.9	17.7
Crimean selection	2191–1	20.2	22.6	22.4
Crimean selection	2576-A	17.1	29.6	23.3
Crimean selection	2578–1	17.1	30.7	23.9
Crimean selection	2903–5	21.3	31.4	26.3
Crimean selection	2908–A	18.7	26.6	22.6
Crimean selection	3055-A	18.2	32.0	25.1
Crimean selection	4430	28.7	33.1	30.9
Crimean selection	1563–2	12.0	27.6	19.8
Crimean selection	1728–1–4	14.7	26.8	20.2
Crimean selection	1571-C	15.6	34.5	25.0
Crimean selection	4337	8.5	20.3	14.4
White Odessa	4651	9.7	22.1	15.9
White Odessa	4655	11.7	35.1	23.4
Martin	4463	21.0	23.5	22.2
Banner Berkeley	....	13.6	26.5	20.0
Red Hussar	4843	17.0	25.2	21.1
Kharkov	1442–12	21.3	29.4	25.3
Turkey x Florence (Wash. No. 326)				
Turkey x Florence selection G314	....	19.8	21.8	20.8
Turkey x Florence selection G316	....	16.9	28.7	22.8
Turkey x Florence selection G324	....	19.1	20.2	19.6
Turkey x Florence selection G326	....	24.6	30.9	27.7
Turkey x Florence selection G330	....	19.5	28.2	23.8
Turkey x Florence selection G332	....	18.9	34.2	26.5
Turkey x Florence selection G334	....	18.8	26.5	22.6

The following is a brief description of the varieties which, from the two years' nursery trial, appear to be the most promising from the standpoint of yield:

Turkey C. I. 1558 A. A selection made from Turkey, C. I. 1558, by Dr. C. R. Ball in 1915. The variety is a typical Turkey wheat. At Corvallis it comes nearest of all the hard red wheats to being free from yellowberry.

Turkey C. I. 1558 B. This variety differs from C. I. 1558 A in that it has a stiffer straw and the heads when ripe stand more erect than in the Turkey variety.

Crimean C. I. 2903-5. A selection from the Mediterranean variety made at Amarillo, Texas. The kernels and plant characters are similar to those of Turkey wheat.

Turkey C. I. 3055. This is a selection from Turkey wheat made at the Highmore Substation at Highmore, South Dakota. The spikes of this variety are somewhat longer and more lax than those of the Turkey variety. The heads are pendant when ripe and do not shatter readily.

Crimean C. I. 4430. This is a pure-line selection from Crimean wheat made by J. A. Clark from a field plot at Moccasin, Montana, in 1915. The heads are large and erect, and are somewhat inclined to shatter. The kernels appear to be similar to those of Turkey wheat.

Turkey C. I. 1571 C. Turkey C. I. 1571 has been one of the highest yielding Crimean wheats tested at the Sherman County Branch Experiment Station. This strain appears identical with Turkey wheat but is considerably more smut-resistant than Turkey C. I. 1571, from which it was selected.

White Odessa C. I. 4655. This is a beardless, red-chaff wheat with white kernels. It has a long slender spike and matures rather late. It is weak-strawed when grown at Corvallis.

Martin Amber C. I. 4463. This is one of the latest maturing wheats of the smut-resistant group. It is a beardless wheat with white chaff and white kernels. It has always been smut-free at Moro and Corvallis and elsewhere so far as is known.

Red Hussar C. I. 4843. The original seed of this variety was obtained from the Illinois Agricultural Experiment Station. It is a pure-line selection that appears to be immune to stinking smut. Bulk seed of the same variety received in the fall of 1920 from the Illinois Experiment Station was not exceptionally smut-resistant. The variety is a bearded wheat with a rather long head. The kernels are large, hard, and red. The variety shatters quite badly at Moro. It has excellent baking qualities.

Turkey x Florence. These are hybrids made by Dr. E. F. Gaines of the Washington Experiment Station. The selections that have been grown in Oregon are all beardless with long, slender heads and white glumes, resembling Florence. They were all supposed to be red but two white strains have been selected from them. The selections are exceedingly smut-resistant, all of them possessing much more resistance than either of the parents, which, in the United States at least, prior to 1917 were the most resistant varieties known. The fact that highly resistant strains have resulted from the crossing of two varieties of only moderate resistance is of the highest significance genetically and promises greater achievements for the future. This phase has been treated by Dr. Gaines in the Journal of the American Society of Agronomy for April, 1920.

As presented in foregoing data, the tests in Oregon of over 800 varieties and strains have resulted in the finding of eighteen or more varieties and selections which show marked resistance or complete immunity to bunt. These include types of hard and soft white, and hard and soft red wheats, some of which have excellent milling and baking qualities. These facts promise much for the eventual elimination of the bunt nuisance from the wheat industry in all parts of the State.

SUMMARY

Seed Treatment Experiments

Bunt or stinking smut is one of the most serious diseases affecting wheat in Oregon.

This disease is caused by bunt spores adhering to the seed after threshing, or by wind-borne spores being deposited on summer-fallowed soil. These spores germinate and send out infection threads, which enter the underground portion of the young wheat plant, grow with it, and finally cause smutted wheat.

Seed-borne spores are the most common method of infection where seed is not treated. Investigations in the summer of 1918 indicate that wind-borne spores cause the principal part of the infection in Eastern Oregon, notably in Umatilla county.

Of the two species of organisms causing bunt *(Tilletia tritici* and *Tilletia levis)*, both are found in the Willamette Valley, but only one, *Tilletia tritici*, is found in Eastern Oregon.

Experiments carried on at several points in Eastern and Western Oregon indicate that both species of bunt are of about equal virulence.

Observations made in Oregon as early as 1912 indicated that seed treatment for bunt frequently was responsible for injury to seed germination and reduction of stands of winter wheat. Since 1912, elaborate experiments have been conducted in cooperation with the Office of Cereal Investigations of the United States Department of Agriculture to determine the effect of seed treatment on germination of seed and on the control of stinking smut. The results of these experiments show that:

(1) Solutions of formaldehyde and bluestone of sufficient strength to kill the smut may, under certain conditions, destroy or delay germination or seriously reduce or impair the vigor of the young growing plants.

(2) Injury to formaldehyde-treated seed is considerably lessened by washing the seed in clear water after treatment.

(3) Injury to seed by the bluestone treatment is also materially lessened by washing or rinsing the seed in a solution of lime water.

(4) In the Moro tests, formaldehyde solutions of 1 pint of commercial formaldehyde to 45 gallons of water and bluestone solutions of one pound to ten gallons of water were equally effective in controlling bunt.

(5) Seed treated with formaldehyde should be sown as soon as possible after treatment, or while seed is damp, and only in moist soil.

(6) Either storing formaldehyde-treated seed or sowing in dry ground is a dangerous farm practice.

(7) The bluestone treatment is to be preferred if the seed is to be stored for any length of time or if the seed is to be sown in dry soil.

(8) The injury caused to seed by the formaldehyde and bluestone treatments usually depends upon the extent of injury done to the seed by the threshing machine.

(9) Elaborate experiments reported in this bulletin show that hand-threshed seed is only slightly injured by the formaldehyde and bluestone treatments.

(10) The treating of seed with dry copper carbonate, which has been found to control bunt in Australia and in California, does not injure the seed. Experiments are in progress to determine whether this treatment will effectively control bunt in Oregon.

Bunt-Resistant Wheat Varieties

Experiments to determine the susceptibility of different wheat varieties to stinking smut were begun at Moro in 1917.

All the commercial wheat varieties of the United States, Australia, and India, as well as hundreds of pure-line selections of wheat varieties, were tested for smut at Moro for the two years, 1919 and 1920. The comparative smut resistance for the two years of the common wheat varieties grown in the Northwest is shown in Table X.

A few pure-line selections of wheat varieties were discovered that are totally immune to both species of stinking smut. Nearly twenty varieties of wheats were found that were so highly resistant to this disease that they can be safely sown without treatment for bunt.

The discovery of these wheat varieties is likely to prove of much economic importance to the wheat-growing industry of Oregon and will probably mean the eventual elimination of the bunt nuisance from the State. This would mean an annual saving to farmers of many thousands of dollars.

In these varieties and pure-line selections of wheat are many different types ranging from soft white to hard red. All of them are being increased and tested for yield in several localities in Oregon.

A brief description of some of the new bunt-immune and bunt-resistant varieties is given on pages 37 to 42.

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Oregon Agricultural College
Experiment Station

Department of Soils

Irrigation of Alfalfa

By

W. L. POWERS
and
W. W. JOHNSTON

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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SUMMARY

1. Due to its adaptability and advantages, alfalfa is the leading irrigated crop, and together with other meadow crops constitutes 52.5 percent of the cultivated acreage on Government projects. Since meadow crops require about twice the water that annual crops need, alfalfa and other meadow crops deserve about three-fourths of the attention in determining the average duty of water for a project.

2. Farm ditches should be large enough to allow for rotation in the use of water and should serve the whole farm directly.

3. A more general use of the strip-border method of irrigation will save time, water, and money.

4. The time and frequency of irrigation should be such as to prevent crusting of newly seeded land and provide moisture before the crop is checked in its growth, or before the soil-moisture content reaches the drought point for alfalfa. A fairly moderate and uniform moisture content should be maintained.

5. The amount to apply at one irrigation will depend largely on the usable moisture capacity of the soil, which ranges from ½ inch per acre foot for coarser soils to 2 inches per acre foot for a silty clay loam. The depth of penetration of water can be determined by using a spade.

6. Duty-of-water experiments for several states indicate that a good return per unit of water is .2 ton of alfalfa per acre inch or a little over 2 tons per acre foot.

7. As an average of 43 net duty-of-water trials in Eastern and Southern Oregon the maximum yield an acre inch was secured with 15.5 inches and the yield of hay obtained was 3.96 tons an acre, while increasing the average depth to 24.15 inches gave an average maximum yield of approximately 4.5 tons an acre.

8. Under sub-humid conditions at Corvallis on a silty clay loam soil as an average of ten water-variation trials, 5.5 inches depth gave a maximum yield per acre inch. Averaging 4.37 tons and increasing the depth to 9.06 inches increased the average yield to 5.04 tons.

9. Maximum net profit per acre with irrigated alfalfa is realized with a smaller amount of water than is required for a maximum yield per acre, but with less than is required for a maximum yield per acre inch. With low costs and plentiful water the maximum yield per acre approaches the maximum profit, but with high costs and a shortage of water the yield per acre inch will come nearer to approaching the maximum net profit.

10. Water requirement of alfalfa for plots giving the maximum net profit was 739 pounds of water per pound of dry matter produced, or 5.23 inches per ton of dry hay.

11. Proper irrigation, fertilizers, and crop rotations are important factors in improving the soil solution and lessening the irrigation requirement. Applications of farm manure and sulfur have substantially increased the average yield per acre and per acre inch in Oregon and reduced the water requirement.

12. As far as possible alfalfa should be fed out on the farm to conserve fertility. Alfalfa land should be broken up every few years to loosen the soil and market the stored-up nitrogen and humus in cash crops. All of this tends to aid in the economical use of water.

Irrigation of Alfalfa

By W. L. POWERS and W. W. JOHNSTON*

INTRODUCTION

Alfalfa, meadow forage crops, and pastures, in connection with livestock husbandry are essential to a permanent system of irrigation agriculture. A first principle is to convert the wonderful growth of legumes and grasses which can be produced under irrigation into such condensed products as butter, beef, mutton, pork, and seed.

Advantages and Uses of Alfalfa. Alfalfa, the leading irrigated crop, is adapted to a great range of soil and climatic conditions. It grows rapidly and throughout the entire season, yielding heavily. Alfalfa adds nitrogen and humus to the soil; its deep roots loosen the subsoil and draw up plant-food elements from the sub-strata. It is a fairly permanent crop and the cost of production is therefore moderate. Alfalfa cures well under the arid conditions and provides nitrogenous substances in sufficient amounts to make it practically a balanced feed. The plant makes a good hay or pasture for stock and makes a valuable seed crop under certain conditions. Its use is being somewhat extended by grinding.

Handling the Crop Under Irrigation. Land should be carefully leveled before seeding to alfalfa, since high spots that will fire out or low spots that will drown out interfere with the maximum yield and duration of the crop. It is desirable to have a rather thick stand as this makes a finer quality of hay. A firm, fine, clean seed bed is desirable in order to secure a good stand. From ten to eighteen pounds of seed should be used; the higher amount may be necessary on new land. A minimum amount is required on loam soil, where seed is tested and shows a high percentage of purity and germination. A good method of seeding is from the grass box attachment on a grain drill. A bushel or so of bald barley or rye is frequently used as a nurse crop and removed early for hay. This may prevent light soil from blowing or in other cases may control weeds. Heavy or late grain crops are apt to injure the stand of alfalfa. As far as possible, hardy varieties such as Grimm should be used. On raw land or in new localities it is best to inoculate the seed, using pure culture from the Experiment Station or soil from a clean alfalfa field.

If the soil is heavy it should be irrigated before seeding unless it is well provided with moisture. Afterwards re-wetting should be avoided till the crop begins to shade the soil. Where the furrow system is used, marking for irrigation should be performed by the time the crop appears above ground. A corrugated roller can be employed if the ground becomes crusted during germination. Some roller should be used which will not leave the ground slick. After the first irrigation when the alfalfa is well rooted and eight or ten inches high, a light weeder can be used. The first season the alfalfa should be clipped off; this will encourage branching and root development. The clipping should be given when the crop turns yellowish, starts secondary shoots, becomes weedy, or starts blooming during its first year. The following spring a springtooth harrow or other alfalfa renovator may be used if the soil is dry enough to work freely before the crop has made any appreciable growth. More vigorous renovating is permissable on old alfalfa meadows, and harrowing is desirable after pasturing and irrigation or manuring. After alfalfa has been grown several years there is a tendency for the soil to become packed on the surface from lack of cultivation; the humus and nitrogen accumulated by the alfalfa sod should therefore be plowed under so that this plant food can be marketed in the grain, the soil being loosened up and cultivated crops used in rotation with the alfalfa. Over irrigation, a water table within less than four feet of the surface, or continued clipping before bloom tend to kill out the stand.

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*Earlier experiments were conducted partly in cooperation with the United States Office of Experiment Stations. The writers also wish to acknowledge cooperation of Harney and Umatilla Branch Experiment Station superintendents, Obil Shattuck and H. K. Dean, and Mr. Douglas Ritchie, Field Agent at Burns the past two seasons. This report is published as a phase of Oregon Soil and Soil Water Investigations provided for in chapter 350, Session Laws of 1919, and its continuation 1921.

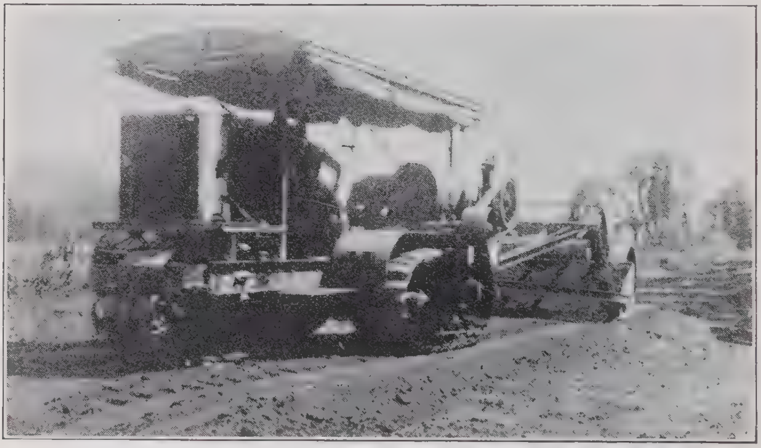

Fig. 1. Land leveler and tractor.

Alfalfa is most easily killed by plowing when it is moist enough so that fermentation will take place. Shallow plowing with a sharp plow provided with a knife for cutting horizontal roots and a second deeper plowing two or three months later before planting time will in many cases be justifiable, particularly where such crops as potatoes are to follow. If one plowing is given, it should be of good depth so as to secure enough fine soil to work down with the sod into a good seed bed. The use of a two-way plow will avoid making dead furrows or back furrows and save work in releveling.

IRRIGATION

Farm Ditches. Farm ditches on new land should be planned to serve the entire tract, and convey the water to the land as directly as possible. Good permanent gates should be provided on farm ditches and these ditches should have capacity to handle fairly large heads of water.

TABLE I. MEAN VELOCITY AND DISCHARGE FOR DITCHES WITH DIFFERENT GRADES

Grade			Mean velocity in feet per second	Discharge in cubic feet per second
Inches per rod	Feet per 100 feet	Feet per mile		
Farm ditch No. 2—16″ base and 6″ depth of water				
¼	.13	6.67	.82	.80
	.25	13.33	1.16	1.00
¾	.38	20.00	1.42	1.30
1	.51	26.67	1.64	1.50
1¼	.63	33.33	1.84	1.70
1½	.76	40.00	2.02	1.80
1¾	.88	46.67	2.18	2.00
2	1.01	53.33	2.34	2.10
2½	1.26	66.67	2.61	2.40
Farm ditch No. 3—2′ base and 9″ depth of water				
⅛	.06	3.33	.79	2.08
¼	.13	6.67	1.13	3.00
½	.25	13.33	1.60	4.20
¾	.38	20.00	1.97	5.20
1	.51	26.67	2.28	6.00
1¼	.63	33.33	2.57	6.80
Farm ditch No. 4—4′ base width and 1′ of water				
1/16	.03	1.58	.84	4.20
⅛	.06	3.33	1.08	1.40
¼	.13	6.67	1.54	7.70
⅜	.19	10.00	1.89	9.50
½	.25	13.33	2.20	11.00
⅝	.31	16.67	2.45	12.20
¾	.38	20.00	2.69	13.40

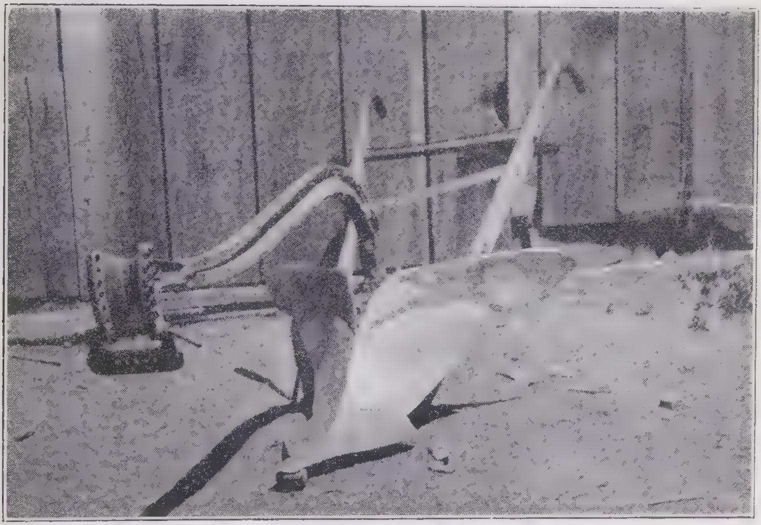

Fig. 2. Lateral plow.

Capacity for farm ditches of various sizes and grades is given in Table I. A lateral plow can be used in opening these trapezoidal-shaped farm ditches, and a V ditcher such as the Martin or Simplex is well adapted to the larger ditches.

There are several methods used for applying water to alfalfa fields, their suitability depending on soil and subsoil, topography, nature of water supply, size of farm, amount available for preparation of land, and the prevailing crops of the district.

The chief methods of applying water to alfalfa in Oregon are: flooding from contour field laterals, strip-border flooding, and furrow or rill irrigation.

Contour Flooding. In this method of irrigation, the supply ditch may be run directly or diagonally down the slope or along the field border and be provided with drops and check gates for taking out water at frequent intervals. From these gates, which will be 5 or 6 rods apart, the laterals will be plowed across the slope nearly on the contour line and having a few inches fall per hundred feet. These field laterals are located by having the rodman pace off 50 feet at a time, the levelman then shifting him up or down the slope to the point of desired elevation. A stake is left at each point located. On sloping land these laterals may be made with the ordinary plow and the dirt thrown out on the down-hill side. The furrow should be gone through twice and then finished with a V-shaped crowder and shovel. Water is turned into these furrows and turned out at frequent intervals and allowed to flow in a thin sheet over the surface extending down to the next lateral below, which serves for an equalizing ditch and distributes water to the next-adjoining land. This method is suitable for undulating land with the slope as high as 10 feet or more in 100 feet. The system is easily installed and gives a

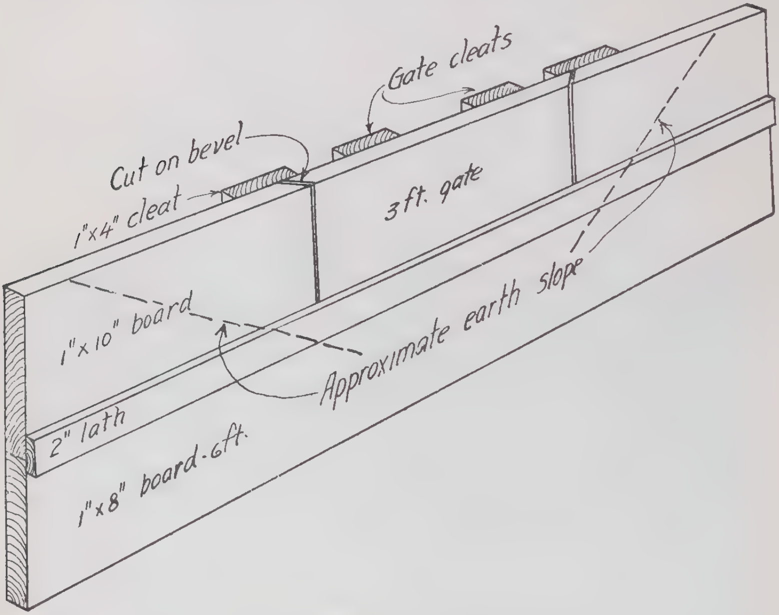

Fig. 3. Head gate. (Bul. 177.)

fairly good distribution of the water. Some waste is usually experienced with this method of irrigation.

Strip-Border Flooding. The border-flooding method of irrigation is used in Malheur Valley, Umatilla Basin, and other sections of the State. It is adapted to gently sloping valley lands, which can be leveled so that the strips will slope in one way. This method is especially suited to alfalfa irrigation after the crop shades the ground. The supply ditch follows the ridge or the highest side of the land; if large, a secondary or header ditch is used to distribute the water to the strips. This ditch has a capacity to carry several second feet and is provided with a good, permanent turn-out gate at the head of each strip. These borders can be started with a Fresno or other scraper while leveling off the land, and can be finished by an adjustable ridger, or they may be thrown up by plowing back-furrows, and throwing in two furrows on each side before using the ridger. A disk turned to throw the dirt to the center is also used in places. The intervening strips are then smoothed down to an even plane. The furrows are nearly filled by this leveling operation. Across the upper end of the strips a table one rod wide should be made level, so that the water will start down the strips in a thin sheet, spreading over this table and down the long narrow strips evenly. Two or more strips may be irrigated at a time. When the water reaches nearly to the lower end it is turned off and another strip started.

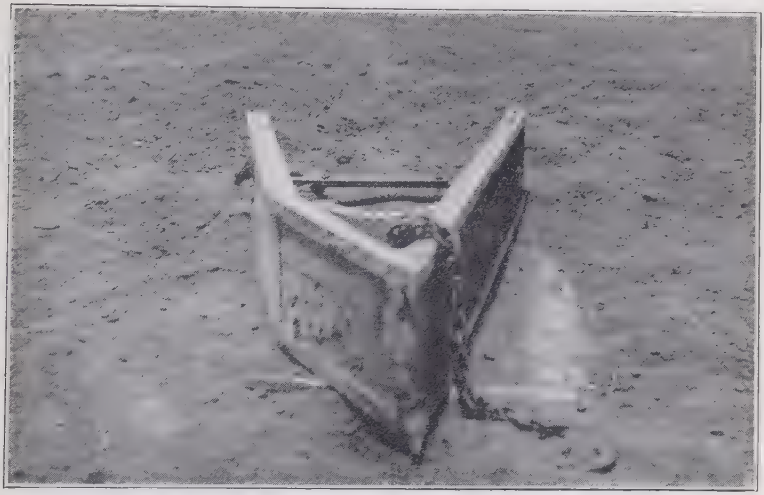

Fig. 4. Lateral clearer.

The *width* and *length* of border will depend upon the soil, slope of the land, and head of water available. On medium sand, at the Umatilla Branch Experiment Station it was found [1] that the length of border should not be over 220 feet. A width of 30 feet was found suitable. Borders should be comparatively small for coarse soils in order to irrigate quickly. On loam soils suitable size of border proved to be 30 to

50 feet wide by 300 to 600 feet long, as determined by experiments in California.[2] On loam soil a length of 330 or 660 feet will divide a forty into lands of equal width. The strips will run directly down the slope, and will be separated by borders which may have a base width of five or eight feet and should be 10 to 12 inches deep at the crown. This border method avoids excessive grading and permits economical preparation and application; affords uniform distribution and usually saves time, water, and money on moderate slopes.

The *size of head* used in irrigating should be fairly large, depending upon the slope and size of strip border. In irrigating with this method, the aim is to get over the land rapidly and wet the whole surface to a uniform depth without deep percolation loss. In the California experiment[2] a head of from two to ten second feet to the strip was found desirable for medium loam soils, and a desirable grade would be from three to six inches to one hundred feet. For clay and clay loam soil, a head of one to four second feet in a grade of from one to three inches per 100 feet was found more suitable. A smaller head would be required on steeper grades. On slightly undulating land the dikes will be placed closer together at the head of the strips where the head ditch goes across or around a ridge in the the land, and will be placed farther apart at the head of the strips in laying out the borders across a depression below the head ditch. The system is adaptable to the general farm under irrigation, and permits fairly good control of the water while enabling a considerable area to be irrigated in a reasonable length of time. This method should be much more generally used in this State, particularly on the general grain, hay, and stock farm, provided the land has a fairly gentle, uniform slope.

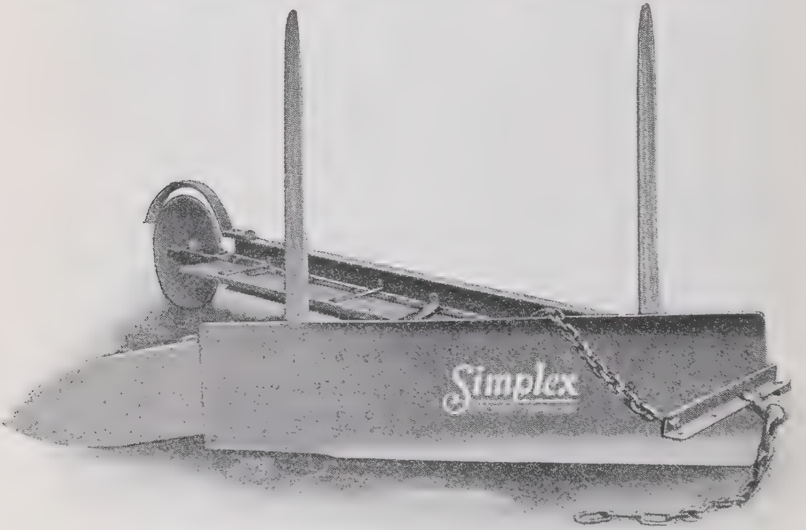

Fig. 5. Simplex ditcher.

Corrugation or Rill Method. This is a modification of the furrow method and is well adapted to districts where diversified, rather intensive agriculture is practiced. It is suitable for lands that will not stand flooding without baking and where the formation favors sub-irrigation or where the irrigating head securable is small. In order to avoid crusting of heavier soils it may be necessary to corrugate new seeding between strip borders the first season and until the crop shades the ground. The method can be used for meadow or grain. Small corrugations are made with a sled (Fig. 8) shod with cultivator shovels or with the regular manufactured corrugators, at intervals of from two to five feet, depending on the capillarity of the soil and substratum. The water is then allowed to flow through these much as in the furrow method of irrigation, the irrigation being continued a sufficient length of time to permit the strips between the corrugations to become moistened, largely by "subbing" and capillarity.

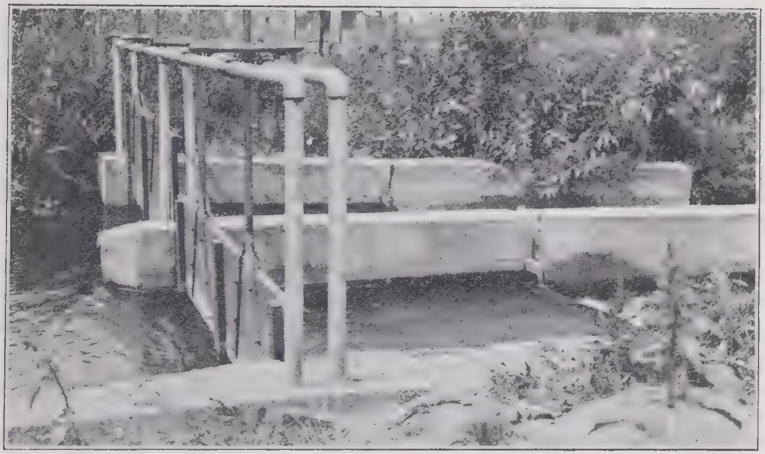

Fig. 6. Simple type of head gates and weirs.

Sub-irrigation. Irrigation by seepage or by underground methods is feasible in this State only where the natural conditions permit its practice without resorting to expensive equipment. In part of Baker Valley there is a strong loam soil underlaid with gravelly substrata in which the water table can be raised and sub-irrigation secured without much danger of water-logging or aggravating the alkali trouble. The gravel is open and seems not to be injured or puddled by this treatment. The water is raised in the sloughs by damming up and sub-surface layers are moistened by "subbing" from occasional field laterals. In the Upper Deschutes Valley and other places where the country is underlaid with porous basalt which gives slow, natural drainage and where the water is fresh and little alkali is found, a sort of sub-irrigation system is practiced. The water is supplied by corrugations and to some extent the soil is filled up with free water which moves laterally and down the slope from one corrugation to the next, moistening the strips between them. With the medium loamy sand soil in the Upper Deschutes Valley uniform wetting will be secured where the corrugations are not over five feet apart.

Checks. The check method of irrigation, wherein land is divided by dikes into rectangular level areas 100 feet wide and 100 to 200 feet long and irrigated by field laterals between each second series of checks, is little used in Oregon. The first cost for fitting land is often heavy for this method of irrigation.

Portable Pipe. Portable slip-joint pipe is sometimes used for irrigation of slightly undulating or sandy land, especially where water is pumped. The pipe is usually connected by means of a portable hydrant to outlets from an underground lateral. The pipes may be 12 to 15 feet long if not more than 5 to 8 inches in diameter and are made of light galvanized or black tarred metal. Ends must be tapered downstream and the upstream ends flanged to fit instantly.

Choice of Methods. The whole purpose of irrigation is to provide a favorable moisture content throughout the root zone and to apply moisture when the soil has reached the drought point in quantities sufficient to raise the moisture to the excess point without waste by deep percolation or running off. Excessive evaporation should also be avoided and everything that possibly can should be cultivated just as soon after irrigation as the soil is dry enough to crumble. To secure economical use of water, it is necessary to have a good distribution system. The selection of this will depend on the nature of the soil, the topography of the land, the size of head of water, and the nature of the crop. General flooding systems will be adaptable to soils which are not inclined to bake and crust. The furrow and corrugation methods are suitable where the soil cannot be safely flooded and for intensive farming or farming where the head of water securable is small. Contour laterals or furrows run down the slope will be almost necessary on steep land. On relatively level land, almost any system may be adopted, but it should be suited to the type and size of the farm. On coarse soils, it is important to have a large head of water and to get over the soil rapidly in order to avoid deep percolation loss. The heavier the soil, the smaller the head; while the flatter the slope is, the larger the head should be. The irrigation farmer should make a study of the problem and choose the system best suited to his conditions rather than follow blindly the practice of the locality. It is best to choose the method which in the long run will give the greatest economy in labor and water and produce the greatest net profit an acre.

IRRIGATION EXPERIMENTS WITH ALFALFA IN OREGON

During the seven-year period 1907-1914, irrigation experiments with alfalfa in Oregon were largely confined to the Home Station farm at Corvallis, and the Umatilla Branch Station. This earlier work has been reported in detail in earlier publications of this Station.[1 3 4] In the spring of 1915 cooperative duty-of-water investigations were started with the Office of Irrigation Investigations, Department of Agriculture; and since then water variation trials and other experiments with irrigation of alfalfa have been conducted, in several of the chief irrigated valleys of the State.

Weather Conditions. The monthly and annual rainfall for stations in localities where duty-of-water experiments or other trials have been under way and herein reported are given in Table II.

TABLE II. NORMAL PRECIPITATION IN ALFALFA SECTIONS OF OREGON

MONTH	Hermiston (451)*	La Grande (2784)	Baker (3471)	Joseph (4100)	Burns (4170)	Lakeview (4950)	Klamath Falls (4100)	Prineville (2864)	Jacksonville (1640)	Corvallis (266)
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	1.14	2.06	1.34	1.84	1.84	2.30	2.45	0.99	4.53	7.22
February	.93	1.93	1.34	1.70	1.34	2.03	1.44	.95	3.69	5.56
March	.63	1.84	1.44	1.97	1.20	1.54	1.23	.71	2.41	4.47
April	.53	1.58	.94	1.66	.79	1.13	.88	.68	1.47	2.88
May	.79	2.32	1.73	2.22	.86	1.43	.99	1.05	1.68	2.19
June	.48	1.51	1.21	1.95	1.09	1.10	.89	.83	.94	1.24
July	.17	.66	.43	1.00	.45	.43	.32	.36	.36	.46
August	.34	.54	.39	.86	.22	.28	.30	.29	.35	.40
September	.29	1.11	.76	1.33	.80	.69	.56	.58	.88	1.59
October	.54	1.51	.91	1.36	.66	.88	.96	.67	1.54	2.79
November	1.19	1.97	1.18	1.94	1.33	1.76	1.60	1.09	3.91	7.18
December	1.12	2.04	1.53	1.77	1.37	1.88	1.78	.85	5.15	6.69
Total	8.15	19.07	13.20	19.60	11.95	15.55	13.39	9.08	26.91	42.67

*Numbers in parentheses indicate elevation.

TABLE III. WATER CAPACITIES OF DIFFERENT SOIL TYPES, SURFACE FOOT

Location	Soil type	Water capacity		Soil wt. per cu. ft.	Estimated excess point	Estimated lento point	Estimated usable water capacity	
		%	in.				%	in.
Hermiston	Coarse sand	18	3.0	88	11	7	4	.7
Joseph	Fine sandy loam	47	5.7	64	30	15	15	1.9
Paisley	Medium peat	147	7.6	28	110	40	70	3.8
	Peaty	64	6.5	52	45	20	30	2.5
	Silt loam	50	5.8	63	34	16	18	2.1
	Sandy loam	30	4.7	84	22	12	10	1.6
	Coarse sand	21	3.5	85	14	7	7	1.1
Klamath Falls	Sandy loam	24	4.2	91	22	14	10.1	1.7
	Medium peat	167	8.5	26.4	150	70	97.0	4.9
	Clay loam	51	5.8	63	48	25	26.0	3.1
Burns	Silt loam	36	4.9	66	35	18	17	2.1
	Very fine sandy loam	38	4.6	64	33	18	15	1.8
Haines	Loam	38	4.0	68	27	12	15	2.0
	Fine sandy loam	33	4.9	68	26	12	14	1.8
Redmond	Medium sand	39	4.1	66	24	12	13	1.6
Lakeview	Medium sand	28	4.5	84	20	11	9	1.5
Grants Pass	Fine sandy loam	23	4.3	85	18	9	9	1.5
Corvallis	Silty clay loam	36	5.5	80	27	14	13	2.0

Soils Used. The soils on which experiments have been conducted range from medium sand at the Umatilla Branch Experiment Station, requiring a maximum amount of water, to the silty clay loam at the Home Station under sub-humid conditions, where the highest duty has been realized. The usable water capacity, the organic content, and other important soil properties of the chief soils employed in these studies are given in Table III. From the study of water capacity of the different soils used the approximate field capacities for different soil classes have been developed. (See Fig. 13.) Some attention has also been given to the extent of root systems and other factors bearing upon the time, amount, and frequency and the duty of water for alfalfa.

In considering these subjects, it should be kept in mind that the whole purpose of irrigation is to provide and maintain a favorable moisture content during the growing season; that the water capacity of soil should be kept up by increasing the organic-matter content and increasing pore space by cultivation, so as to afford the greatest possible storage of water; also that the usable water should be conserved to avoid unnecessary run-off, percolation, evaporation, and transpiration losses.

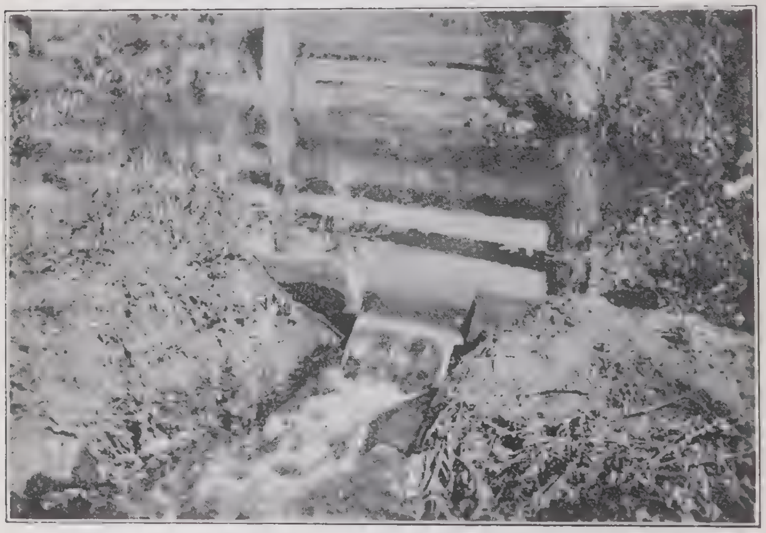

Fig. 7. Small portable weir.

Time of Irrigation. Theoretical considerations affecting the time of irrigation are appearance of the crop, weather conditions and evaporation, soil-moisture content, and water supply.

Any indication of wilting on sandy spots in the alfalfa fields, the yellowing of lower leaves, or dark green color, are indications of need of irrigation.

Evaporation from a water surface is a valuable indicator of weather influences and gives the combined effect of the drying influences of the different weather elements. Weather conditions must be watched, and though little dependence should be placed on prospective showers, heavy irrigation should be avoided if there are strong indications that heavy showers may fall.

The soil-moisture content is a very valuable guide as to the need of irrigation, and the minimum and excess points for important soils are presented in Table II above referred to. Alfalfa will be checked in its growth when the moisture content of the soil drops below the "lento" point or point below which water moves with less freedom in the feeding root zone, but growth will continue slowly until the actual wilting point is reached. Plants may be kept alive by moisture secured by deep tap roots, but there is not enough to cause good growth except when there is usable moisture in the feeding root zone. According to experiments in the Imperial Valley and elsewhere [illegible] as much as 90 percent of the feeding roots of alfalfa may occur in the first four or five feet of soil, in some sections in Oregon within 3 feet. A good supply of usable moisture should therefore be maintained in the feeding root zone. If alfalfa is allowed to go without water until it is checked in its growth, it is slow to recover [3] and is inclined to "harden off", whereas it should be kept in a tender succulent condition. In Utah tank experiments a uniform, moderate moisture content was found best for alfalfa. [7]

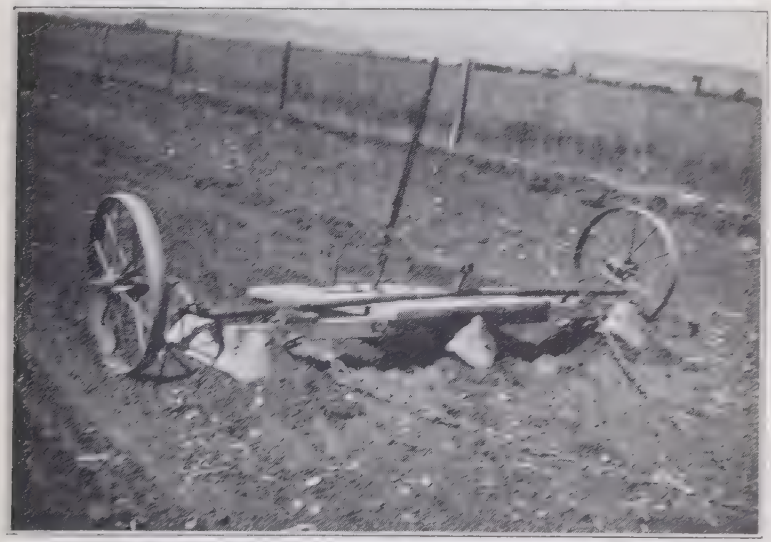

Fig. 8. Home-made corrugator.

Irrigating the Seed Bed. Where flood irrigation is necessary or late irrigation water is limited, the water supply will necessitate the storing of the water in the soil to some extent as available.

Moisture should be stored in the soil in goodly amounts at seed time and the drilling will form a mulch so that it will tend to help store this moisture, which in loamy soils should carry the plants until they shade the ground before further irrigation. If natural rainfall has not stored a good supply of moisture, irrigation before seeding would be desirable. Irrigating before the crop is up may interfere with germination, except on the sandier soils that are not inclined to crust. Under such conditions, it will perhaps aid germination, bring the soil in better contact with the seed, and make it firm, so that the young sprout will have a shorter distance to grow to the surface.

Irrigation Before vs. After Cutting. Experiments to determine the relative value of irrigation before as compared with after cutting conducted in different states show little difference and no uniform opinion. [9] [10] Both cutting and irrigating check the growth of alfalfa temporarily. If irrigation can be given when the plant shades the ground and begins to bloom, it will bring on the second crop earlier. Irrigation before cutting should be early enough so that the ground will not be soft when cutting the hay. Under field conditions growth may be checked by delaying irrigation until after the hay crop is cured and removed from the land. Irrigation before cutting, while desirable, may not be possible except when the land is well fitted so that an even distribution can be secured without tramping down the crop already produced.

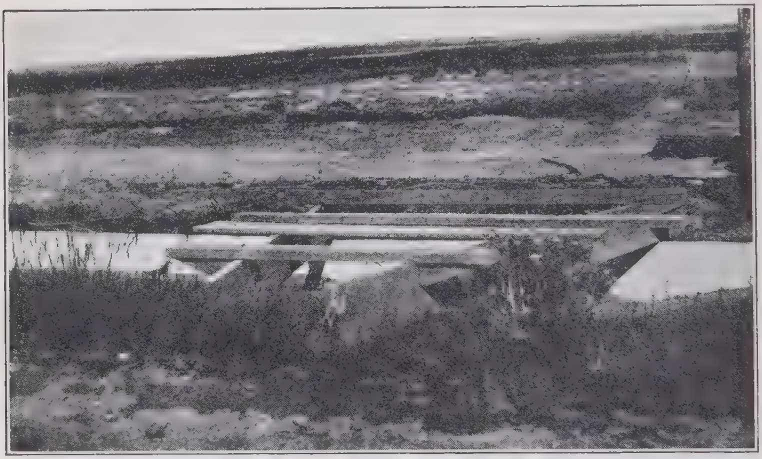

Fig. 9. Ridger used in preparation of strip borders on a concrete lateral.

Winter Irrigation is desirable where complete storage is not provided, but should not begin until the plants are in a dormant stage, and can be practiced at any time the ground is not frozen and will take up more water. Where the climate is very dry and it is better to have a moderate supply of moisture in the land over winter to aid chemical and bacterial processes, flood irrigation in late winter or early spring is very valuable, and helps avoid winter killing. Saturating the surface may cause winter killing, while a moderate moisture content in the soil is a protection against it.

According to Nevada studies, [8] irrigation at different periods and stages of growth has little effect upon the total yield of alfalfa.

Frequency of Irrigation. Theoretical considerations affecting the frequency of irrigation are the storage capacity of the soil and subsoil, rate of loss of moisture, depth of roots and age of crop, depth of ground water, and methods of applying irrigation. On the sandy soils as at the Umatilla Station, [1] it has been found best to apply water to alfalfa every two weeks; on sandy loams at a moderate elevation in Deschutes Valley, where two or three cuttings are secured, two irrigations at a cutting are better than one. On heavy soil at the Home Station at Corvallis, one irrigation at a cutting is sufficient. At the latter place the soil retains enough moisture to sustain growth four or five weeks, or sufficient to produce a good cutting.

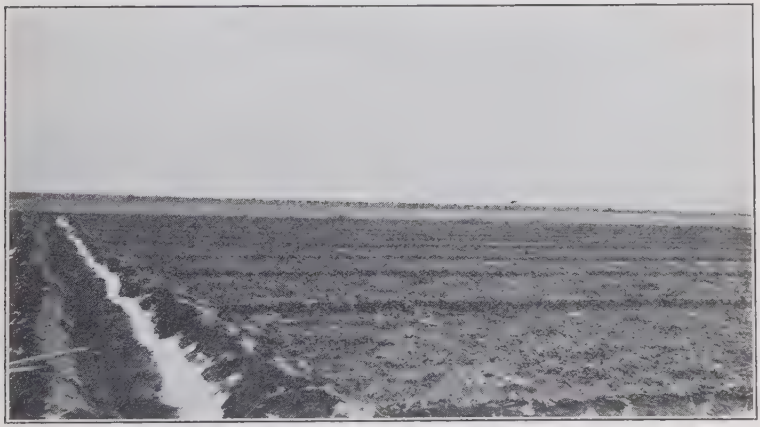

Fig. 10. Land fitted for strip-border irrigation, Harney Valley Branch Experiment Station.

Amount per Irrigation. The amount to apply depends upon the storage capacity of the soil for usable water, the depth of roots, capillary movement to the roots from below, and extent to which the soil has dried out. As indicated by the water-capacity data, medium sand at the Hermiston Station will retain about two-thirds inch of usable water to the acre foot, and fine sand about one inch, while the heavy silty clay loam at Corvallis retains nearly two inches to the acre foot of usable water.

Capillarity in heavier soils operates to a further extent, but may remove water too moderately. In the sandy soils, capillary movement is more rapid, yet the distance it conveys water is limited.

The depth to which a given measured amount of irrigation will penetrate can be determined by the use of a soil auger or spade. Studies of this kind to learn the depth to which the irrigation penetrates, to determine its distribution, should be made until a person is familiar with conditions. Sandier soils require lighter and more frequent irrigation.

Results of experiments bearing on time, amount, and frequency of irrigation for alfalfa reported in an earlier bulletin of this Station are shown graphically in Fig. 15.

Amount per Season or Duty. Duty of water refers to the quantity of water required to mature a unit area of crop. A score or more of factors affecting the duty of water have been previously described.[4] The U. S. crop census figures show that on the Government projects, alfalfa and meadows occupy 52½ percent of the area, and since meadows need twice the water that annual crops require, they deserve 75 percent of the consideration in fixing an average duty for projects. On this account water variation trials at this Station have been chiefly with alfalfa during recent years.

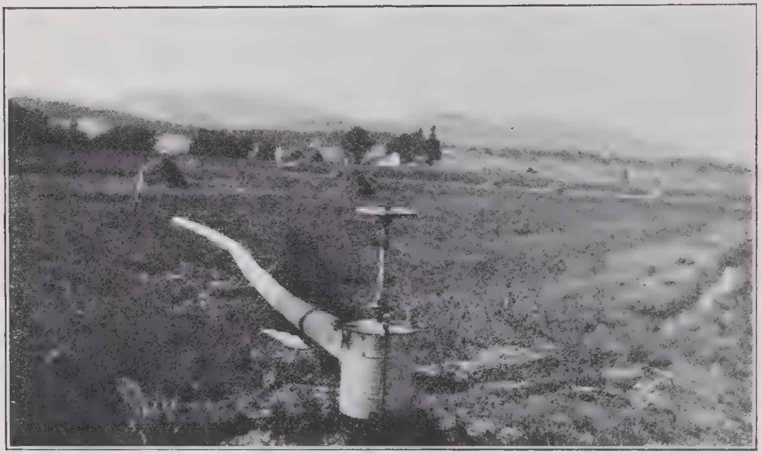

Fig. 11. Portable hydrant and distribution pipe.

Use Records. Duty of water for a given crop, such as alfalfa, is indicated to some extent by measurement of water used under representative field conditions. A large number of measurements of the water used for definite areas have been determined by the U. S. Office of Irrigation Investigations, the Reclamation Service, and other agencies. While these show the actual use, they do not afford information as to whether more or less water would have been better. The average depth applied in 1918 on twenty-two Government projects was 2.75 feet.

Water-variation trials have been conducted by most of the western Experiment Stations, frequently in cooperation with the Government Office of Irrigation Investigations. One of the earliest of these water-variation trials on alfalfa was conducted by Dr. S. Fortier at the Montana Station[12] as early as 1903. A chief objection to net duty-of-water experiments or water-variation trials has been the limited areas, which do not permit the losses experienced under field conditions. To combine the field and plot method, Bark devised a method of field-variation trials.[13] It consists of dividing a representative field and crop into three or four portions of five or ten acres each. The owner then applies to one portion the quantity he customorily uses. The second portion is given from thirty to fifty percent more, and a third portion from thirty to fifty percent less. This method has been used in the different irrigated valleys of Oregon during recent years. [5] Frequently a fourth plot has been added to which has been applied manure or sulfur, and upon which some different method of distributing water has been used with a view to improving the practice. Duty of water experiments with plots from one-tenth acre up to a few acres in area, conducted by western experiment stations, are summarized in Table IV.

TABLE IV. RESULTS OF EXPERIMENTS ON NET DUTY OF WATER—ALFALFA FROM WATER-VARIATION TRIALS IN DIFFERENT STATES

				Quantity giving most economical duty			
State and authority	Soil	Length of trial	Precipitation	Depth of irrig.	Yield per acre	Yield per A. inch	Yield per A. foot
		yrs.	in.	in.	tons	tons	tons
Idaho—Bark[13]	Loam	5	12	32.0	5.47	.16	2
Utah—Harris, F. S.[14]	Loam	17	15	40.0	4.75	.12	1.4
California—Beckett et al.[12]	Fine sandy loam	5	17	36.0	9.27	.25	3.0
Nevada—Knight et al.[8]	Sandy clay	10	8	40.5	5.76	.15	1.8
New Mexico—Thompson[15]	Sandy loam	7	6	36.0	4.00	.12	1.4
Montana—Fortier[12]	Loam	2	10	20.0	4.20	.21	2.5
Wyoming—Buffum[16]	Loam	4	10	31.0	7.80	.25	3.0
Oregon E. Ore. (Aver.)	Clay loam to sandy loam	7	12	30.7	3.83	.12	1.4
W. Ore.*	Silty clay loam	14	42.3	7.5	4.93	.65	7.8
Average	....	....	11.15	33.3	5.63	.17	2.06

*Omitted from average.

The yield per acre foot or acre inch gives opportunity for comparison as to returns of experiments under the climatic and soils conditions of different states. It will be noted that under good conditions a yield of about two-tenths ton an acre inch was obtained, or a little better than two tons an acre foot.

Results of Irrigation Experiments with Alfalfa in Oregon (Table V). Table V presents the results of applying different amounts of water, in several of the chief irrigated valleys of Oregon, the data being grouped according to geographic divisions of the State. Frequently the light irrigations give better returns per unit of water, while the heavier ones give better returns per unit of land. In many cases the average or moderate amounts of irrigation have given the best returns from both standpoints, and represent the application yielding the most profit to the acre.

TABLE V. RESULTS OF OREGON DUTY OF WATER TRIALS—ALFALFA

Year	Project	Soil	Plot area	Total amount of irrigation	Yield per acre	Yield per acre inch
		Umatilla Valley				
			acres	inches	tons	tons
1914		Coarse sand	.2	116.28	5.57	.047
			.2	63.12	5.31	.085
			.2	52.56	4.03	.077
1915		Coarse sand	.2	84	5.69	.067
			.2	44	4.63	.105
			.2	28	3.50	.125
1916		Coarse sand	.2	84	6.72	.080
			.2	44	6.36	.146
			.2	28	4.25	.151
1917		Coarse sand	.2	63	6.45	.102
			.2	44	5.97	.136
			.2	35	4.10	.116
1918		Coarse sand	.2	60	6.13	.102
			.2	45	5.48	.122
			.2	40	4.40	.110
1919		Fine sand	.2	25	8.83	.333
			.2	25.5	8.58	.327
			.2	35	9.12	.293
1919		Coarse sand	.1	63	5.28	.082
			.1	84	4.00	.035
			.1	114	3.88	.044
1921	Borders	Medium sand	.1	32	5.35	.167
			.1	36	5.79	.154
			.1	39	6.27	.155
1921	Checks	Medium sand	.2	40	5.01	.063
			.2	106	5.35	.050
			.2	111	4.07	.036
1921	Borders	Very fine sand	.2	20.5	8.27	.402
			.2	25	7.40	.292
			.2	28	9.56	.341
1921	Checks	Very fine sand	.2	31	7.82	.251
			.2	38	7.86	.204
1921	Borders	Medium sand	.1	27	7.17	.236
			.1	32	6.97	.220
			.1	48	6.07	.127
1921*	Long borders	Coarse sand	.167	77	1.12	.030
			.167	89	2.35	.010
			.167	120	.97	.008
1921*	Short borders	Coarse sand	.1	48	1.81	.037
			.1	59	2.03	.034
			.1	72	2.21	.030
1921		Fine sand	.1	27	8.25	.310
			.1	37	8.50	.230
			.1	42	7.43	.170
		Powder Valley				
1915		Fine sandy loam	62.0	9.07	3.238	.035
		Gravelly loam	21.0	17.49	4.225	.024
1916		Fine sandy loam	6.0	17.5	5.12	.298
			8.4	15.8	3.561	.225
			11.6	12.61	3.225	.225

TABLE V. RESULTS OF OREGON DUTY OF WATER TRIALS (Continued)

Year	Project	Soil	Plot area	Total amount of irrigation	Yield per acre	Yield per acre inch
		Grande Ronde Valley				
			acres	inches	tons	tons
1916	25—38E	Dark loam	2.75	14.37	6.5	.452
			2.75	12.12	5.4	.446
			2.75	9.87	4.3	.435
		Wallowa Valley				
1915		Sandy loam	4.30	33.68	3.092	.092
			4.30	22.33	3.052	.136
			4.30	18.79	3.086	.164
		Harney Valley				
1917*		Very fine sandy loam	.1	6	0.233	.039
			.1	12	0.508	.042
			.1	18	0.533	.040
			.1	12+10T Manure	0.476	.040
			.1	6	0.444	.074
			.1	12	0.812	.068
			.1	18	0.968	.054
			.1	12+10T Manure	0.786	.065
1918		Very fine sandy loam	.1	6	0.635	.106
			.1	12	.640	.137
			.1	18	1.045	.091
			.1	12+10T Manure	1.260	.105
			.1	6	1.475	.246
			.1	12	3.435	.286
			.1	18	4.000	.222
			.1	12+10T Manure	2.825	.235
1919		Very fine sandy loam	.1	7.7	1.13	.141
			.1	11.7	2.36	.201
			.1	15.7	3.61	.230
			.1	11.7+10T Manure	2.25	.192
			.1	7.7	1.96	.254
			.1	11.7	2.67	.228
			.1	15.7	2.97	.189
			.1	11.7+10T Manure	1.52	.130
1920		Very fine sandy loam	.1	7	4.94	.702
			.1	10	3.07	.387
			.1	12	2.55	.212
			.1	10+10T Manure	2.31	.231
			.1	7	5.0	.710
			.1	10	2.42	.242
			.1	14	5.9	.423
			.1	10+10T Manure	3.28	.328
		Chewaucan Valley				
S 25—33 S. 19 E		Sandy loam	2.53	16.65	3.102	.190
			3.16	12.40	2.238	.182
			2.38	6.10	2.318	.371
1916	23—33 S 18 E	Sandy loam	2.53	32.00	6.102	.187
			3.16	21.12	4.388	.207
			2.38	11.16	4.368	.392
1917		Coarse gravelly sand	1.59	12.37	0.858	.073
			1.65	9.87	1.292	.130
			1.46	5.50	1.089	.198
			1.00	99.00	1.7	.017
			1.00	30.00	1.428	.048
			1.00	14.00	1.058	.076

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*Not included in average.

TABLE V. RESULTS OF OREGON DUTY OF WATER TRIALS (Continued)

Year	Project	Soil	Plot area	Total amount of irrigation	Yield per acre	Yield per acre inch
		Klamath Basin				
			acres	inches	tons	tons
1917		Sandy loam	.1	15	4.32	.221
			.1	12.27	3.84	.313
			.1	10	2.70	.270
1919		Clay loam	.35	18.33	2.05	.112
			.35	13.70	1.18	.086
			.35	7.81	.88	.112
1919		Sandy loam	.5	15.5	4.98	.321
			.5	10.5	4.68	.443
			.5	6.0	4.36	.726
		Deschutes Valley				
1912	Redmond Dem. Farm			18	3.3	.18
				25	3.4	.13
1918*	G. Errickson Grange Hall	Medium sand	1	12	.9	.075
			1	15.5	1.0	.064
			1	19	1.1	.058
	E. S. Williams Powell Butte	Med. loamy sand	1.3	8	.95	.118
			1.3	10.5	1.0	.095
			1.3	14.5	1.10	.075
1919	R. Flickinger Tumalo		1	14	2.06	.147
			1	17	2.12	.124
			1	20	2.5	.125
			1	19	2.4	.126
			1	24	2.9	.120
			1	29	3.0	.103
	Geo. Errickson Grange Hall	Medium sand	1	18	3.7	.205
			1	22	4.2	.192
			1	26	4.7	.181
	E. Atkinson Redmond	Med. loamy sand	1	20	3	.150
			1	24	3.1	.129
			1	28	3.95	.141
	W. R. Davidson Terrebone	Med. loamy sand	1	22	3.3	.167
			1	26	4.55	.175
			1	32	5.59	.174
1920	Geo. Errickson Grange Hall	Medium sand	1	20	3.0	.150
			1	24	3.5	.146
			1	28	4.0	.143
	E. B. Williams Powell Butte	Med. loamy sand	3	34	2.9	.085
			17.5	28	2.8	.10
	E. A. Griffin	Med.-coarse sand	4	28	3.7	.132
	Alex Chase Deschutes	Gravelly sand	6.5	28	2.6	.093
			6.5	46	3.1	.067
	Hoskins Redmond	Med. loamy sand	.75	20	2.6	.130
			.75	24	3.25	.135
			.75	28	3.50	.125
	Steffin Tumalo	Med. loamy sand	15.75	20	2.2	.110
			1.85	24	3.25	.135
			1.85	31	4.15	.134
	Cline Falls Ranch	Medium sand	3	20	3.0	.150

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*Not included in average.

TABLE V. RESULTS OF OREGON DUTY OF WATER TRIALS (Continued)

Year	Project	Soil	Plot area	Total amount of irrigation	Yield per acre	Yield per acre inch
		Rogue River Valley				
			acres	inches	tons	tons
1920		Antelope clay adobe	.14	0	3.18	......
			.14	5	4.53	.906
			.14	12	5.09	.424
			.14	13.5	4.35	.322
			.14	12 M. 10 T.	3.39	.203
1921		Antelope clay adobe	.14	0	1.36	......
			.14	5	1.91	.382
			.14	10	2.22	.222
			.14	15	1.92	.128
			.14	10 M. 10 T.	2.13	.213
		Willamette Valley				
1910*	(Experiment Sta.) Corvallis	Silty clay loam	.1	0	4.9 green	......
			.1	10	16.9 green	1.15 green
1911	(Experiment Sta.) Corvallis	Silty clay loam	.1	0	2.17	......
			.1	5	4.36	.872
			.1	8	4.51	.564
			.1	12	5.22	.437
1912*	(Experiment Sta.) Corvallis	Silty clay loam	.1	0	4.00 green	......
			.1	5	6.37 green	1.27 green
			.1	10	10.37 green	1.03 green
			.1	12	7.52 green	.626 green
1913	(Experiment Sta.) Corvallis	Silty clay loam	.1	0	2.15	......
			.1	4	3.8	.950
			.1	6	4.2	.700
			.1	8	4.2	.525
1914	(Experiment Sta.) Corvallis	Silty clay loam	.1	0	2.1	......
			.1	5	2.2	.440
			.1	10	2.6	.260
			.1	10	2.4	.240
1916	(Experiment Sta.) Corvallis	Silty clay loam	.1	0	2.8	......
			.1	4	4.2	.105
			.1	6	5.2	.866
			.1	8	4.2	.525
1917	(Experiment Sta.) Corvallis	Silty clay loam	.1	0	3.74	......
			.1	5	4.23	.845
			.1	7.5	5.31	.708
			.1	10.5	5.31	.506
1918	(Experiment Sta.) Corvallis	Silty clay loam	.1	0	4.47	......
			.1	8	5.7	.712
			.1	12	7.3	.608
			.1	16	6.6	.413

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*Not included in average.

TABLE V. RESULTS OF OREGON DUTY OF WATER TRIALS (Concluded)

Year	Project	Soil	Plot area	Total amount of irrigation	Yield per acre	Yield per acre inch
			acres	inches	tons	tons
1920	(Experiment Sta.) Corvallis	Silty clay loam	.1	0	3.3	......
			.1	5	5.3	1.006
			.1	7	4.9	.700
			.1	9	5.4	.600
1921	(Experiment Sta.) Corvallis	Silty clay loam	.1	0	3.6	......
			.1	6	4.18	.696
			.1	10	5.13	.513
			.1	14	4.43	.316

Average Duty of Water by Valleys (Table VI). The duty-of-water data as summarized in Table VI show the quantity of water giving the maximum yield an acre inch for each trial, and the quantity giving a maximum yield an acre. While in some cases with rapid underdrainage it is practically impossible to irrigate alfalfa to the point where decrease in yield occurs, still beyond a reasonable amount of water the percentage of increase is very slight. The use of water, like the use of fertilizers and other farm treatments, is subject to the law of diminishing returns. The maximum profit is obtained by use of an amount a little short of the quantity that will give the maximum yield to the acre and a little more than the quantity that will give the maximum yield to the acre foot. From the experiments at Corvallis, the cost of production and irrigation, and the crop value have been figured from year to year, so that the average amount of irrigation giving the maximum net profit has been determined.[4]

TABLE VI. AVERAGE OF ALL REPRESENTATIVE DUTY OF WATER TRIALS—ALFALFA—IN OREGON

Oregon Agricultural College Experiment Station—Department of Soils

Valley	No. of trials, 3 plots each	Quantity of water giving best returns			
		Best return per unit of water		Maximum yield per acre land	
		Water used, acre	Yield per acre	Water used per acre	Yield per acre
		in.	tons	in.	tons
Umatilla	15	36.0	6.19	60.0	6.90
Powder	2	13.3	4.18	17.5	4.68
Grande Ronde	1	14.3	6.50	14.3	6.50
Wallowa	1	18.8	3.09	33.7	3.09
Harney	8	10.2	3.26	14.7	3.84
Chewaucan	3	7.6	2.60	19.3	3.50
Klamath Basin	3	12.2	3.42	16.3	3.78
Deschutes	13	22.5	3.18	30.7	3.83
Rogue River	2	5.0	3.22	11.0	4.15
Willamette* (Corvallis)	10	5.5	4.37	9.06	5.04
Average	58	15.54	3.96	24.15	4.49

*Not included in average.

Indicated Economic Duty by Valleys. As an average of 43 net-duty-of-water trials in Eastern Oregon the maximum yield an acre inch was secured with 15.5 inches and the yield of alfalfa obtained was 3.96 tons an acre, while increasing the average depth to 25.15 inches gave the maximum yield an acre as approximately 4.5 tons as an average.

In Umatilla Basin (altitude 500 feet; annual rainfall, 8 inches; sandy soils) 36 inches depth a year gave the greatest yield per unit of water, or an average yield of 6.19 tons, while 60 inches depth gave but 6.9 tons as an average maximum yield an acre.

In Powder Valley (loam soil, 3500 feet elevation, 13 inches annual rainfall) increasing the depth used from 13 to 18 inches, increased the yield half a ton an acre.

Under similar conditions with the somewhat lower elevation of Grande Ronde Valley, 14.3 inches gave best returns.

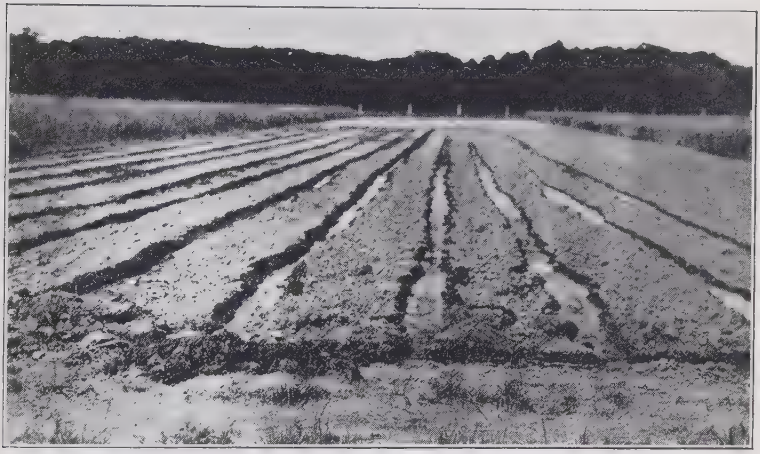

Fig. 12. Corrugation method of irrigation on new seeding.

On fine sandy loam soil in Wallowa Valley with 20 inches annual rainfall and 4000 feet altitude, increasing the annual depth of irrigation from 19 inches to 34 inches increased the yield but very slightly.

As a result of eight trials in Harney Valley on very fine sandy loam at 4100 feet elevation under annual rainfall of 8 to 10 inches, increasing the depth from 10.2 inches to 14.7 increased the yield .56 ton an acre.

In Chewaucan and Klamath basins under similar conditions as in Harney Valley 12 to 19 inches was required.

Trials on adobe soil in Rogue River Valley, with 1200 feet elevation and 20 inches rainfall, gave a maximum yield per acre inch with 5 inches depth and a maximum yield an acre with 11 inches depth per season.

Thirteen water-variation trials on medium sandy loam soils at about 3000 feet elevation in Deschutes Valley, with rainfall of 12 inches a year, gave a maximum yield per acre inch of 3.18 tons with a net application of 22.5 inches; increasing the depth applied to 30.7 inches gave a maximum yield an acre of 3.85 tons.

At the Home Station at Corvallis, on silty clay loam soil at 266 feet elevation and in a sub-humid climate with 42.6 inches rainfall, ten water-variation trials resulted in an average maximum yield of 4.37 tons per inch where 5.5 inches was used, and an average maximum yield per acre of 5.04 tons from use of 9.06 inches depth a season.

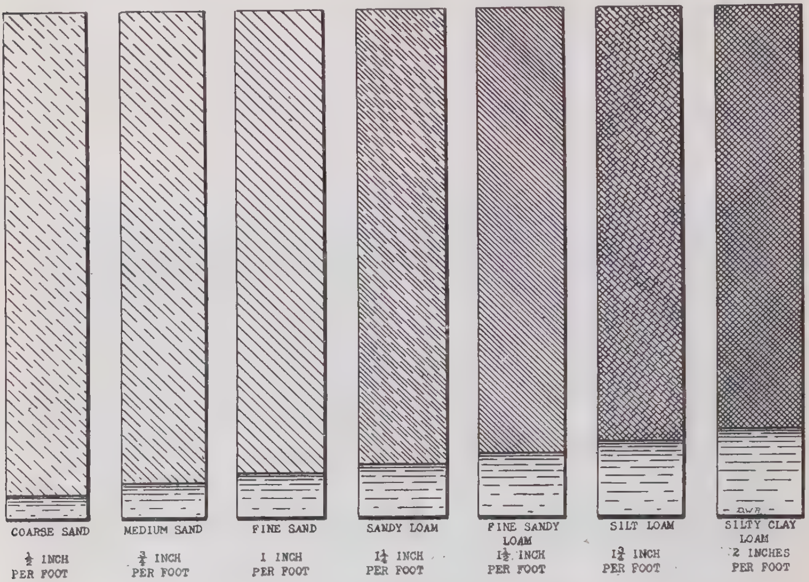

Fig. 13. Water capacity of soil classes.

TABLE VII. WATER REQUIREMENT OF ALFALFA IN OREGON

Oregon Agricultural College Experiment Station—Department of Soils

			Pounds water per pound dry matter with irrigations giving	
Valley	Total yearly precipitation	Irrigation per season	Best return per acre inch	Best return per acre
	in.	in.	lb.	lb.
Chewaucan	15.55	23	1136	2432
Harney	11.95	12	733	909
Powder	13.20	12	660	756
Umatilla	8.15	55	1040	1040
Wallowa	18.49	25	1112	1639
Klamath	13.39	12	674	858
Willamette	42.16	8	725	769

Water Requirement of Alfalfa. (Table VII). Since duty of water is an expression of ratio of water consumed to crops produced, the water cost or *water requirement* of varous crops is an expression of this ratio of water to crop. *Irrigation requirement* is used to refer to the portion of total water requirement needed to be supplied artificially. In an arid country where rainfall and soil water are almost negligible the irrigation requirement will approach closer to the water requirement. The water requirement has been determined in most of the Oregon experiments. In the experiments at the Home Station the water cost for the plot which each year has given the maximum net profit has been calculated. The average for the plot giving the greatest profit for each year has also been determined for all years of the experiment. This average water requirement is 739 pounds of water to one of dry alfalfa, and is equivalent to 5.23 inches per ton of dry hay. This water requirement has been closely approached in the Eastern Oregon field experiments. At the New Mexico Experiment Station under good conditions the water requirement of alfalfa was found to be 774 pounds per pound of dry matter.[15] At the Utah Station it was near one thousand and increased with heavy irrigation.[19]

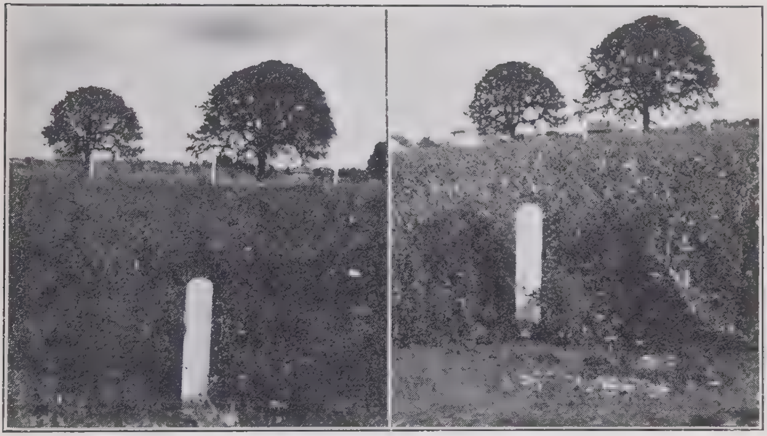

Fig. 14. Irrigated vs. unirrigated alfalfa, Corvallis (September).

Water requirement varies with a dozen or more factors, transpiration being the chief source of dissipation of water from cropped fields. The figures given herein represent the evapo-transpiration ratio and they have an important bearing on the duty of water. The water requirement has been found to vary as much as 18 or 20 percent from year to year, just as crop yields vary with good seasons and bad seasons. Water requirement varies with the stand of crop and with the fertility of the soil and the tilth, is affected by the time and amount of irrigation, and varies with the climate. A low water cost will be realized where large yields are obtained and soil is of good tilth and fertility. It is believed that the water requirement is a very valuable indicator of the highest probable duty or crop-producing power of water.

Crop-Producing Power of Water. (Table VIII). Using the average water cost of the most profitable plots at the Home Station at Corvallis, or 739 pounds per pound dry matter, equivalent to 5.23 inches per ton dry alfalfa, the water requirement for different yields has been calculated as shown in Table VIII. It represents the crop-producing power of water under good conditions and indicates the highest probable duty of water. On this basis a three-ton arid region should need 15 to 18 inches of usable water, and a six-ton region, 30 to 36 inches. This applies fairly well to Eastern Oregon conditions and some of the other irrigated sections. With sub-irrigation, very high yield, very fertile soil, or in case of very coarse soil, this figure will require some qualification.

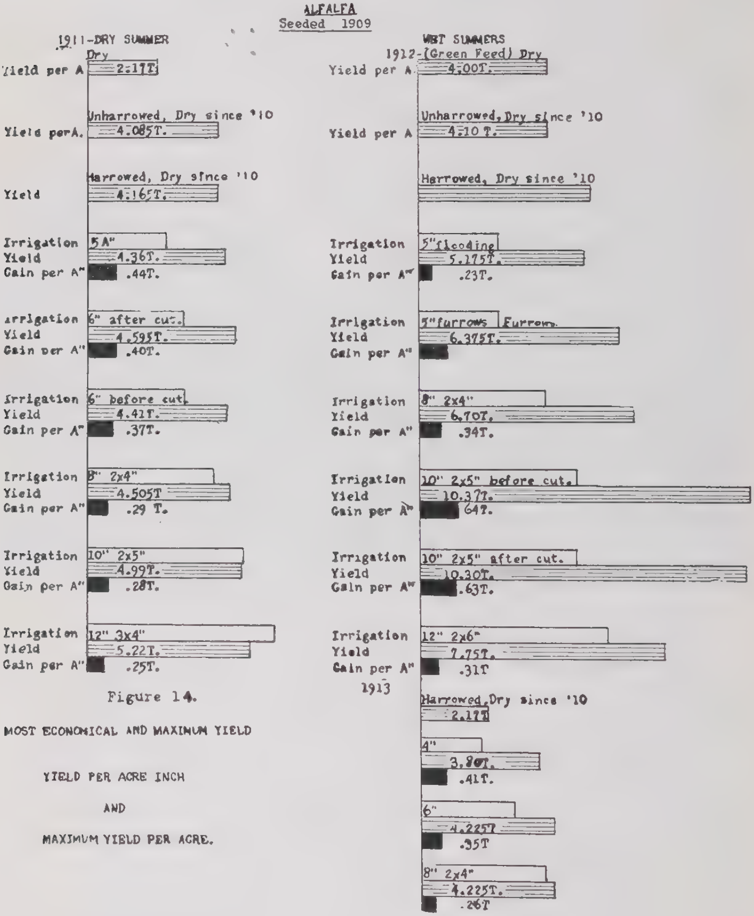

Fig. 15. Effect of amount and frequency of irrigation, Corvallis plots.

Figs. 16, 17, 18. Duty of water plots, Klamath.

TABLE VIII. CROP-PRODUCING POWER OF WATER—ALFALFA BASED ON GOOD AVERAGE WATER REQUIREMENT

Yield per acre	Acre inches required
tons	A. in.
1	5.23
2	10.46
3	15.69
4	20.92
5	26.15
6	31.38
7	36.61

Fig. 19. Stacking alfalfa with nets.

TABLE IX. EFFECT OF PROPER AMOUNT OF IRRIGATION ON WATER REQUIREMENT, ALFALFA

Oregon Agricultural College Experiment Station—Department of Soils

	Dry	Light irrigation		Med. irrigation		Heavy irrigation	
Year	Water requirement	Irrigation	Water requirement	Irrigation	Water requirement	Irrigation	Water requirement
		in.		in.		in	
1910	1135	......	....	10	488	......	....
1911	814	5	622	8	730	12	648
1912	1317	5	996	10	726	12	1045
1913	1111	4	716	6	843	8	866
1914	1785	5	1685	......	....	10	1606
1916	815	4	553	6	583	8	667
1917	473	5	571	7.5	416	10.5	568
1918	547	8	365	12	366	16	489
1920	474	5	464	7	484	9	532
1921	326	6	461	10	515	14	702
10-year Aver.	880	5.2	715	8.5	572	11	780

Effect of Proper Irrigation on Water Requirement. (Table IX). The water requirement for the dry plots and plots with light, medium, and heavy irrigation for alfalfa at Corvallis for all years is summarized in Table IX to show the relation between the amount of irrigation and water requirement. A moderate amount of irrigation reduced the water requirement to considerably below that of the dry plots, for the water comes during the best growing weather. With heavy irrigation water is wasted and water requirement greatly increases.

Economical use of water is important if the greatest net profit per acre is to be secured in growing alfalfa. The more water used the more woody, and the less water the richer the product in blood-and muscle-forming elements. Over-irrigation injures the soil and crops or may involve needless expense in application, reducing the net profit per acre.

Effect of Fertilizer on Water Requirement and Irrigation Requirement. (Table X.) As early as 1912 Oregon experiments which included fertility trials showed variation in yield per unit of irrigation water, and this was also recognized by Bark in his Idaho experiments. [13]

Table X is arranged to show the effect of sulfates on alfalfa as determined at Redmond in 1912, and the increase in the yield an acre inch where fertilizers are applied.

In these experiments wherever fertilizer was effective there was a large increase in the production of dry matter for the same amount of water applied, and this gave a decidedly better return per acre foot of water. It is entirely possible and very desirable under irrigation to build up the water capacity and available fertility of the soil so as to maintain a richer plant-food solution and enable the dry matter to be

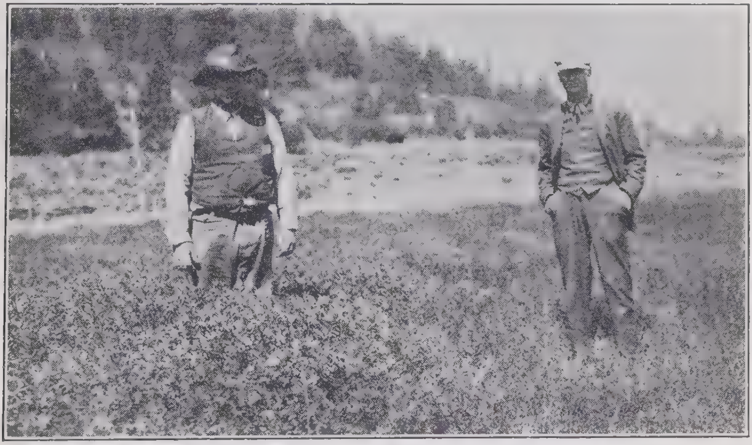

Fig. 20. Sulfur vs. no sulfur.

TABLE X. RELATION OF SOIL FERTILITY TO ECONOMICAL USE OF IRRIGATION WATER

Oregon Agricultural College Experiment Station, Irrigation Demonstration Farm, Redmond, 1912

Crop	Irrigation, total depth	Fertilizers per acre	—Yield per— Acre	of water Acre inch	—Gain in— Yield T.	Value	Cost of fertilizer	Profit (or loss)
	in.	lb.	tons	tons				
Alfalfa	21	None	3.00	.143	....	....	....	.....
Alfalfa	21	Potas. sulf 160	3.96	.186	.96	8.68	4.00	4.68
Alfalfa	21	Gypsum 60	3.40	.162	.41	3.69	.45	3.24
Alfalfa	21	Potas. cl. 160	3.27	.165	.27	2.43	4.00	—1.57
Old clover	24	None	3.33	.138	....	....	....	......
Old clover	24	Potas. sulf. 160	5.04	.210	1.71	15.39	4.00	11.39
Old clover	24	Gypsum 60	3.48	.145	.25	2.25	.45	1.80

produced at a more economical water cost. In other words, "the richer the soup the less required" by the crop per pound of hay produced.

Fertilizers for Alfalfa (Tables XI and XII). Fertilizer experiments on alfalfa in Oregon have been conducted for several years in the Deschutes Valley, in the Rogue River Valley in Southern Oregon, and at the Umatilla Branch Experiment Station; and some tests with sulfur and farm manure and rotation have been carried into the other valleys of the State in recent years. The results of some of the longer experiments are presented in Tables XI and XII.

TABLE XI. SUMMARY OF ALFALFA FERTILIZER TRIALS, DESCHUTES VALLEY

Soils Department, Oregon Agricultural College Experiment Station. Trials mainly in 1912 and 1918, '19, 20 (Ave. all years.)

Fertilizer	No. of trials	Average rate per acre Applied	Average rate per acre Value	Average yield per acre	Average increase over check plot	Net value of increase at $20 a ton
				tons	tons	
Sulfur	8	80	$3.20	4.85	1.73	$34.60
Gypsum	10	52.5	.37	3.75	.67	13.03
Phosphorous	6	280	5.12	3.95	1.10	16.88
Nitrogen	6	80	3.20	4.00	1.14	19.60
Muriate of potash	4	140	13.90	3.09	.62	—.80
Sulfate of potash	2	120	8.75	5.23	1.33	17.85

TABLE XII. FERTILIZER EXPERIMENT ON ALFALFA, MEDFORD, OREGON. SOIL EXPERIMENT FIELD*

Plot	Treatment Fertilizer	Treatment Amt. per acre	Yield per acre, average for six years 1916-1921
		lb.	lb.
1	Check	0	987
2	Sulfur	600	4073
3	Sulfur	100	4610
4	Sulfur	300	5240
5	Gypsum	595	5740
6	Mococo residue	1541	5450
7	Monocalcic phosphate	317	1190
8	Superphosphate	823	5210
9	Muriate of potash	534	1030†
10	Sulfate of potash	594	4890
11	Check	0	1090
12	Nitrate of soda	558	1150
13	Sulfate of ammonia	423	5350
14	Iron sulfate	870	5370
15	Magnesium sulfate	782	5370
16	Sodium sulfate	1033	4510
17	Pyrites	263	1780
18	Check	0	880

*Experiment initiated by F. C. Reimer, superintendent of the Southern Oregon Branch Experiment Station.

†Average for 4 years only—1916-19.

Experiments covering several years have increased the alfalfa yield to the extent of practically double the yield per acre foot from certain treatments. Sulfur has increased alfalfa yields by 1 to 2 tons an acre in most of the arid and semi-arid sections and will make at least 1 ton increase on 100,000 acres of alfalfa in Oregon.

At the Umatilla Branch Experiment Station the use of eight tons of manure an acre, as an average of a four-year period, increased the alfalfa yield by 1.33 tons an acre, [1] and where so treated has given an increase of about a quarter ton per acre foot applied. A fertilizer experiment at the Harney Branch Experiment Station with alfalfa gives indication that manure reinforced with acid phosphate will prove to be the best treatment there.

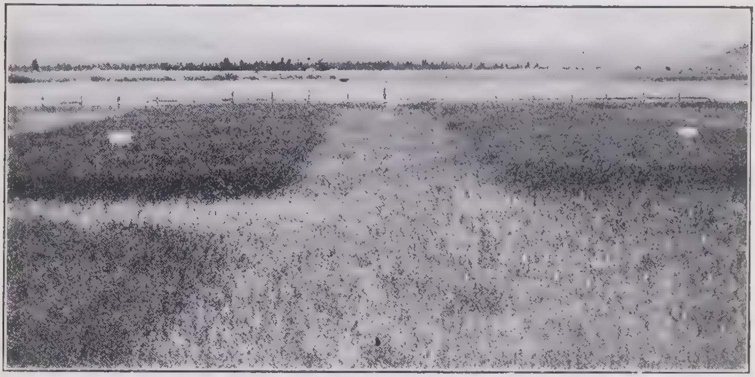

Fig. 21. Effect of sulfates, Reimer plots, Southern Oregon Soils experiment field.

Irrigation of Alfalfa for Seed Production. Light, frequent irrigation is best where alfalfa is grown for seed production in order that a uniform, moderate moisture content may be maintained. Much less water is required for seed production. At the Aberdeen Branch Station in Idaho, [17] light irrigation and early clipping of the first growth was found to increase the seed yield. At the Gooding Branch Station in Idaho, [18] light irrigation and clipping about May 1 in connection with seed

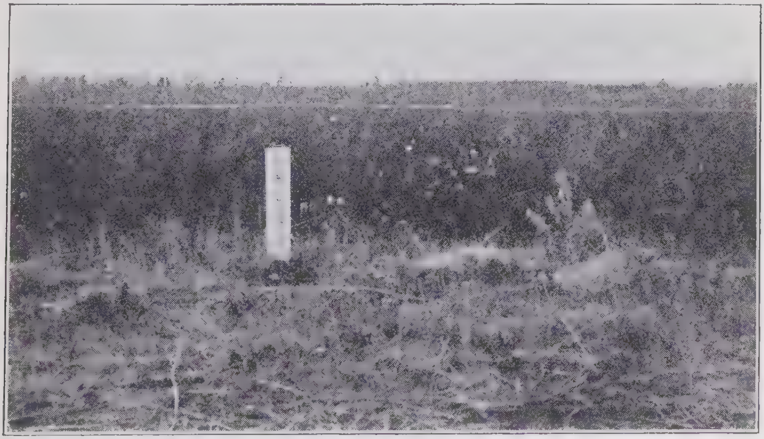

Fig. 22. Original sulfate plots, Redmond, 1912.

production was found good; a thin stand with rows thirty-five inches apart was found desirable. As the plant comes to the blooming period, a lower moisture content to avoid secondary shoots and encourage maturity is believed desirable in production of alfalfa for seed.

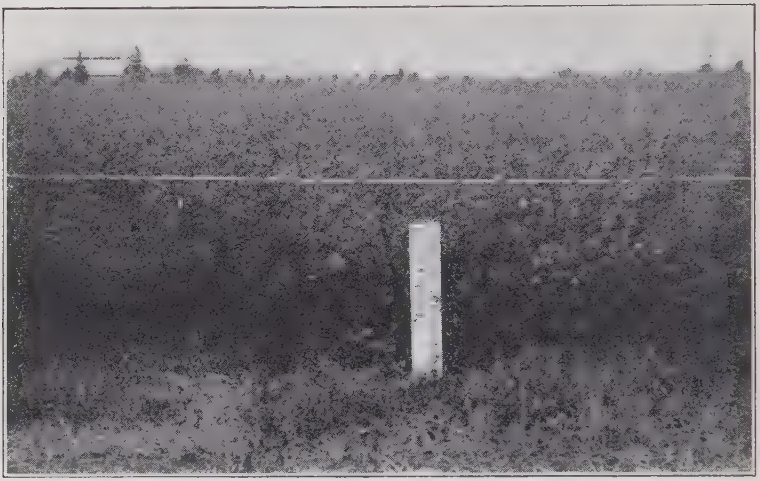

Fig. 23. Original sulfate plots, Redmond, 1912, sulfate of potash.

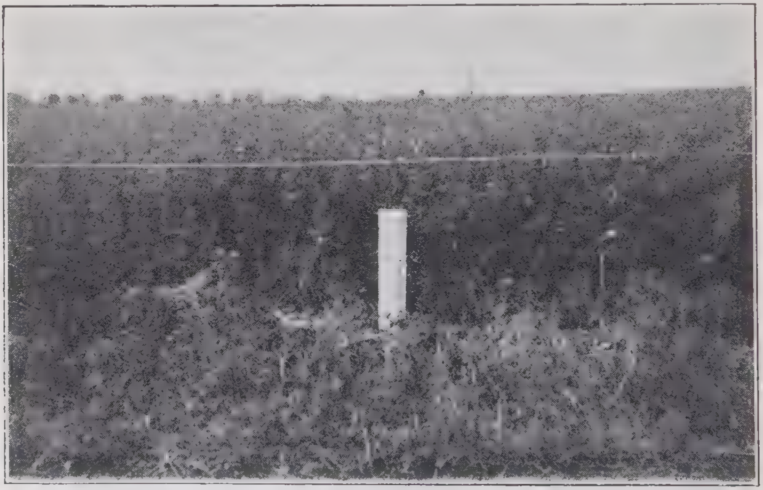

Fig. 24. Original sulfate plots, Redmond, 1912, chloride of potash.

Harvesting and Marketing. The irrigated region permits curing alfalfa hay so that a high-quality product can be realized. In harvesting care should be used to retain the leaves as these are the most nutritious part of the hay; raking as soon as wilted is desirable as is placing in small cocks promptly to avoid excessive exposure to the sun and avoid bleaching. Grinding in order to condense the product is practiced to some extent where alfalfa is shipped, but in the interest of permanent irrigation agriculture, alfalfa should be fed out on the land to retain the fertility on the farm. Since alfalfa hay has high feed value, high fertilizer value is realized from farm manure produced in connection with the use of such feed which contains abundant protein. In earlier experiments irrigation of alfalfa had a beneficial effect upon the succeeding potato crop. Potatoes on irrigated alfalfa sod gave double the yield with a water requirement one-fourth less than did potatoes grown on unirrigated alfalfa sod land. Crop rotation with use of manure from the feed lot makes it possible to market the nitrogen and humus accumulated in the alfalfa sod in the form of cash crops; it also helps to avoid alfalfa pests.

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Oregon Agricultural College

Experiment Station

Wheat Growing After Fallow in Eastern Oregon

By

D. E. STEPHENS and G. R. HYSLOP

CORVALLIS, OREGON

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SUMMARY

Wheat is the most important crop in Eastern Oregon. About a million and a quarter acres are annually devoted to raising wheat in the eighteen counties east of the Cascade Mountains.

Wheat is principally grown after summer fallow. The area sown to wheat, exclusive of the summer-fallowed area, is about equal to that of all other cereals and forage crops combined.

Winter wheat generally outyields spring wheat, except under irrigation.

Nearly all Eastern Oregon soils are adapted to wheat growing. On the lighter soils of the drier areas, wheat has been found to be the farmer's most profitable crop.

PREPARATION OF SOIL FOR GROWING WHEAT AFTER FALLOW

Experiments at the Moro Station show that fall disking of stubble reduces wheat yields. Spring disking before early spring plowing also does not pay.

Spring disking before late spring plowing kills weeds, saves moisture, and increases yields.

Burning stubble is likely to deplete the soil of needed vegetable matter and ultimately cause it to run together and be more subject to washing and gullying. Stubble should never be burned in the fall. The standing stubble holds snow and aids in getting moisture into the soil.

Highest yields and best quality of wheat are produced on early-spring-plowed summer fallow. Careful experiments at Moro for nine years have proved that the average yields of winter wheat after early spring plowing were 6.3 bushels an acre more than after late spring plowing and 2.3 bushels an acre more than after medium early spring plowing.

The total increase in yield for early over late plowing in nine years was 56.7 bushels an acre, or the equivalent of two and one-half years of crop on late plowing.

Fall plowing and medium early spring plowing for summer fallow give similar yields.

Late spring plowing for fallow produces low yields and soft wheat.

The nine-year average yield of ten-inch over five-inch plowing at Moro was only .9 bushel of wheat.

Mold-board plowing in the fall gave slightly higher yields of winter wheat than disk plowing in the fall at Moro.

The summer fallow should be cultivated frequently enough and in a manner to prevent weed growth and maintain a cloddy mulch.

The use of the subsurface packer at Moro did not increase wheat yields. The surface packer gave only slightly increased yields.

SEED TREATMENT

All present commercial wheat varieties should be carefully treated for stinking smut. For sowing in dry soil, the bluestone treatment is best. Formaldehyde-treated seed should be sown soon after treatment and in moist soil.

Some smut-immune and several highly smut-resistant winter wheats have been produced at the Moro Station.

TIME, RATE, AND DEPTH OF SOWING WHEAT

Good, uniform stands of spring or winter wheat are always desirable. Thin or irregular stands encourage weed growth and reduce yields.

Early sowing of winter wheat at four to five pecks of treated seed an acre gave the highest yields at Moro. Generally deep seeding of winter wheat should be avoided.

Early sowing of spring wheat always pays. Most spring varieties should be sown at four to five pecks an acre. Large kerneled varieties, like Early Baart, should be sown thicker.

CULTIVATION OF THE GROWING CROP

Harrowing winter wheat in the spring generally reduces yields. The nine-year average yield of winter wheat at Moro was reduced one bushel an acre by spring harrowing. In three of these years an increased yield was obtained from the harrowed grain and in the other six years a decreased yield. If winter wheat is harrowed in the spring it should be done when the soil is not badly crusted or when the crust has been softened by rain.

WHEAT VARIETIES

There are forty-one commercial wheat varieties grown in Eastern Oregon. These could profitably be reduced to not over seven.

The results of a varietal trial with forty-one wheat varieties at the Moro Station are shown in Table XI on page 27.

The highest-yielding winter wheats were Kharkov, Argentine, Turkey No. 1571, Hybrid 123, and Hybrid 128. A brief description of these varieties is given on pages 26 to 29.

The results of a varietal trial with spring wheat are given in Table XII. Early Baart, Hard Federation, and Federation spring wheats distributed from the Moro Station have practically replaced Pacific Bluestem spring wheat, the commonly grown variety in Eastern Oregon, with an increase in yield of from 20 to 30 percent.

A comparison of the milling and baking values of five winter and five spring wheats is shown in Table XIII. Winter wheat produced more bushels to the acre but was not of as good milling quality as spring wheat. Kharkov was the best milling winter wheat variety. Hard Federation, Federation, and Early Baart are good milling spring wheats.

Wheat Growing After Fallow in Eastern Oregon

By

D. E. STEPHENS and G. R. HYSLOP

INTRODUCTION

Wheat is the most important farm crop in Eastern Oregon. In the eighteen counties east of the Cascade Mountains there were in 1919, according to the United States Bureau of Census, more than 700,000 acres devoted to the raising of wheat for seed. There were also about 127,000 acres of cereals, mostly wheat, cut for forage. As practically all wheat grown in this section is alternated with fallow, there were in 1919 at least 1,250,000 acres of land devoted to wheat raising for seed and perhaps an additional 100,000 acres were cut for hay. According to the census figures, the acreage in barley ranked second for the cereals in these counties with approximately 52,000 acres, rye third with 36,000 acres, and oats fourth with 32,700 acres.

There were also in these counties about 500,000 acres devoted to forage crops other than cereals. The acreage in wheat for seed and hay, exclusive of the fallowed area, therefore, was about equal to that of all other cereals and forage crops combined.

In Table I is given the annual and average production of spring and winter wheat* for each county in Oregon for the years 1919 to 1921, inclusive. There were six counties in the State with an average annual production in excess of a million bushels of wheat. Each of these counties was in Eastern Oregon. In total average production for the three years, the counties rank as follows: Umatilla, Sherman, Morrow, Gilliam, Wasco, Union.

The total average production of winter wheat in the State for the three years was about four and one-half times the total production of spring wheat. In most counties of the State, winter wheat considerably outyields spring wheat, as is shown in Table II. In the counties of high altitude where wheat is grown under irrigation the average acre yield of spring wheat is better than that of winter wheat.

Since the Moro Experiment Staton† was established, methods for culture of wheat in the Columbia Basin have changed largely because of practices worked out at the Experiment Station and varieties proved or introduced by it.

The wheat crop of the Columbia Basin in Oregon is now much more certain than formerly. Yields are higher, and due to new summer-fallow

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*Production data furnished by F. L. Kent, Agricultural Statistician, Bureau of Markets and Crop Estimates, United States Department of Agriculture.

†The Branch Experiment Station at Moro in Sherman County was established in 1909. It is maintained cooperatively by the State of Oregon, through legislative appropriation, and by the United States Department of Agriculture, through appropriation by the Office of Cereal Investigations of the Bureau of Plant Industry. The soil is a representative silt loam type of the Columbia Basin uplands and varies in depth from four to seven feet to the basalt. The annual average precipitation at Moro is 11.53 inches, practically all of which falls from September to June, inclusive. The average evaporation from a free-water surface for a seven-month period, April to October, inclusive, is 44.89 inches. The average frost-free period at Moro is 145 days.

TABLE I. ANNUAL AND AVERAGE PRODUCTION, IN BUSHELS, OF WINTER AND SPRING WHEAT IN OREGON, BY COUNTIES, FOR THE YEARS 1919 TO 1921, INCLUSIVE

County	Winter wheat				Spring wheat				Three-year average, all wheat
	1919	1920	1921	Average	1919	1920	1921	Average	
	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.
Western Oregon—									
Benton	276,940	217,316	135,000	209,752	96,180	108,000	78,000	94,060	303,812
Clackamas	593.236	502,500	378,000	491,245	66,976	66,930	80,000	71,302	562,547
Clatsop	2,160	1.560	1,250	1,657	651	750	500	634	2,291
Columbia	23,374	25,500	20,000	22,958	9,984	12,000	8,000	9,995	32,953
Coos	1,392	2,400	3,000	2,264	2,898	8,100	6,250	5,749	8,013
Curry	405	750	625	593	39	200	500	246	839
Douglas	178,470	155,200	175,000	169,557	65,925	67,200	60,000	64,375	233,932
Jackson	129,087	244.000	143,000	172,029	14,196	45,900	24,000	28,032	200,061
Josephine	22,032	27,200	28,000	25,744	5,460	6,000	9,800	7,087	32,831
Lane	384,446	282,006	216,000	294,151	172,653	242,240	180,000	198,298	492,449
Lincoln	5,698	4,500	6,000	5,399	612	1,000	2,000	1,204	6.603
Linn	739,728	395,675	288,000	474,468	285,180	263,190	336,000	294,790	769.258
Marion	847,675	749,570	523,600	706,948	214,415	212,876	210,000	212,430	919,378
Multnomah	68,256	54,000	22,500	48,252	15,532	16,470	22,000	18,001	66,253
Polk	628,672	606,280	420,000	551,651	60,350	65,170	90,000	71,840	623,491
Washington	655,255	520,000	400,000	525,085	46,200	40,158	90,000	58,786	583,871
Yamhill	777,878	512,256	516,000	602,045	30,457	32,256	90,000	50,904	652,949
Eastern Oregon—									
Baker	84,513	122,000	115,000	107,171	227,528	238,700	261,000	242,409	349,580
Crook	12,945	12,000	16,000	13,648	29,748	71,600	180,000	93,783	107,431
Deschutes	2,928	2,400	2,000	2,443	11,986	16,360	26,000	18,115	20.558
Gilliam	764,916	1,002,112	2,160,000	1,309,009	261,288	393,400	320,000	324,896	1,633,905
Grant	10,410	11,340	12,000	11,250	10,824	21,200	13,500	15,175	26,425
Harney	2,970	3,000	3,400	3,123	7,758	13,500	13,500	11,586	14,709
Hood River	4,400	2,500	3,750	3,550	3,990	3.000	8,000	4,997	8,547
Jefferson	152,559	191,400	216,000	186,653	126,250	301,150	408,000	278,467	465,120
Klamath	7,623	30,000	18,000	18,541	100,254	180,000	200,000	160,085	178,626
Lake	30,613	37,400	27,000	31,671	54,362	80,000	360.000	164,787	196,458
Malheur	18,384	30,000	21,000	23,128	124,656	125,000	125,000	124,885	148,013
Morrow	891,390	1,151,410	2,346,000	1,462,933	96,040	200.200	240,000	178,747	1,641,680
Sherman	2,028,402	2,650,450	3,240,000	2,639,617	121,992	144,870	135,000	133,954	2,773,571
Umatilla	4,904,064	5,740.000	6,750,000	5,798,021	304,125	353,800	270,000	309,308	6,107.329
Union	517,154	686,907	676,000	626,687	451,388	617,700	560.000	543,029	1,169,716
Wallowa	242,874	453,675	440,000	378,849	197,110	257.148	270,000	241,419	620,268
Wasco	1,230,432	1,311,000	1,500,000	1,347,144	65,280	126,000	75,000	88,760	1,435,904
Wheeler	23,748	45,600	40,000	36,449	4,662	7,000	12,000	7,887	44,336
Total	16.265,029	18,053,907	20,862,125	18.393.687	3.286.949	4.339,068	4,764.050	4,130,056	22,523,742

TABLE II. ACRE YIELDS, IN BUSHELS, OF WINTER AND SPRING WHEAT IN OREGON, BY COUNTIES, FOR THE YEARS 1919 TO 1921, INCLUSIVE

County	Winter wheat				Spring wheat			
	1919	1920	1921	Average	1919	1920	1921	Average
	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.
Western Oregon—								
Benton	20.0	22.0	18.0	20.0	14.0	18.0	15.0	15.7
Clackamas	28.0	30.0	24.0	27.3	23.0	23.0	20.0	22.0
Clatsop	36.0	30.0	25.0	30.3	31.0	25.0	20.0	25.3
Columbia	26.0	30.0	25.0	27.0	24.0	30.0	20.0	24.7
Coos	24.0	30.0	30.0	28.0	23.0	27.0	25.0	25.0
Curry	15.0	25.0	25.0	21.7	13.0	20.0	20.0	17.7
Douglas	18.0	16.0	20.0	18.0	15.0	14.0	15.0	14.7
Jackson	21.0	20.0	22.0	21.0	13.0	15.0	16.0	14.7
Josephine	16.0	16.0	20.0	17.3	10.0	12.0	14.0	12.0
Lane	19.0	18.0	18.0	18.3	13.0	16.0	12.0	13.7
Lincoln	14.5	20.0	20.0	18.2	12.0	20.0	20.0	17.3
Linn	22.0	17.0	18.0	19.0	15.0	15.0	14.0	14.7
Marion	25.0	23.0	22.0	23.3	19.0	19.0	15.0	17.7
Multnomah	27.0	30.0	25.0	27.3	22.0	27.0	22.0	23.7
Polk	22.0	23.0	21.0	22.0	17.0	19.0	15.0	17.0
Washington	29.0	26.0	25.0	23.3	20.0	23.0	20.0	21.0
Yamhill	25.5	23.0	24.0	24.2	19.0	18.0	18.0	18.3
Eastern Oregon—								
Baker	13.0	20.0	20.0	17.7	17.0	22.0	18.0	19.0
Crook	15.0	12.0	20.0	15.7	12.0	20.0	20.0	17.3
Deschutes	12.0	12.0	20.0	13.7	13.0	20.0	20.0	17.7
Gilliam	12.0	16.0	24.0	17.3	9.0	14.0	16.0	13.0
Grant	15.0	20.0	20.0	18.3	11.0	20.0	15.0	18.7
Harney	10.0	15.0	17.0	14.0	9.0	15.0	15.0	13.0
Hood River	22.0	25.0	25.0	24.0	21.0	20.0	20.0	20.3
Jefferson	9.0	11.0	18.0	12.7	5.0	9.5	12.0	8.8
Klamath	11.0	15.0	18.0	13.7	11.0	15.0	20.0	15.3
Lake	11.0	17.0	18.0	15.3	14.0	20.0	24.0	19.3
Malheur	24.0	30.0	30.0	28.0	24.0	25.0	25.0	24.7
Morrow	10.0	13.0	23.0	18.7	7.0	10.0	16.0	11.0
Sherman	19.0	22.0	27.0	22.7	12.0	15.0	18.0	15.0
Umatilla	24.0	28.0	30.0	27.3	15.0	20.0	18.0	17.7
Union	22.0	27.0	26.0	25.0	14.0	20.0	20.0	18.0
Wallowa	18.0	23.0	22.0	21.0	10.0	18.0	18.0	15.3
Wasco	21.0	23.0	25.0	23.0	10.0	18.0	15.0	14.3
Wheeler	12.0	20.0	20.0	17.3	9.0	10.0	12.0	10.3
Average	19.9	22.4	25.5		12.5	16.2	16.8	

methods and better varieties, much new land has been added to successful wheat production.

This change is the result of early plowing, clean fallow, and drought-resistant wheats. There is now less loss from poor stands, dry years, and hot winds, and there is more production of wheat of better quality.

Standardization of varieties is bringing increased yields with very little increase in production cost.

SOILS

Nearly all plow soils in Eastern Oregon are adapted to wheat growing. This crop, however, does best on comparatively light sandy loam and silt loam types, but considerable wheat is grown on many of the heavier loam soils in the valleys of the Blue Mountain section. Where irrigation is practiced, alfalfa and other crops are generally grown, though considerable wheat has also been grown under irrigation during the past few years. On the lighter soils of the drier areas, wheat has been found on the average to be the farmer's most profitable crop.

CLIMATE

In the counties of Oregon east of the Cascade Mountains there is a wide variation of climate. The annual precipitation varies from 7 to 25 inches. Temperatures also vary widely depending upon elevation and location. Low winter temperatures prevail over most of the area, and in the central and southern counties frost during the summer months is not uncommon. Winter wheat can safely be grown over most of the area. It is the only cereal except rye that will ordinarily survive except in a few favored localities where the winters are sufficiently mild to permit the growing of winter barley.

PREPARATION OF SOIL FOR WHEAT

Yields of wheat may be markedly influenced by soil tillage methods. In Eastern Oregon, especially where the rainfall is 15 inches or less, nearly all wheat is raised after summer fallow.

Summer-fallowing for wheat production has been practiced in Eastern Oregon for more than thirty years. Farmers found that higher wheat yields could be obtained by summer-fallowing than by continuous cropping. Many farmers in dry-land sections of Eastern Oregon have tried various crops as a substitute for fallow but usually without general success. Even in the most favored locations where cultivated crops can be profitably grown, farmers still practice summer-fallowing. They contend that the yields of such crops as corn and peas do not pay for the usual reduction in the yields of winter wheat as compared with growing this crop after fallow. Crops, like peas, requiring seeding at the time of spring plowing for fallow, or that are harvested during wheat harvest, have not proved popular with farmers. Late-harvested crops, like corn, especially in dry falls, may leave the soil too dry to insure proper seed germination of winter wheat.

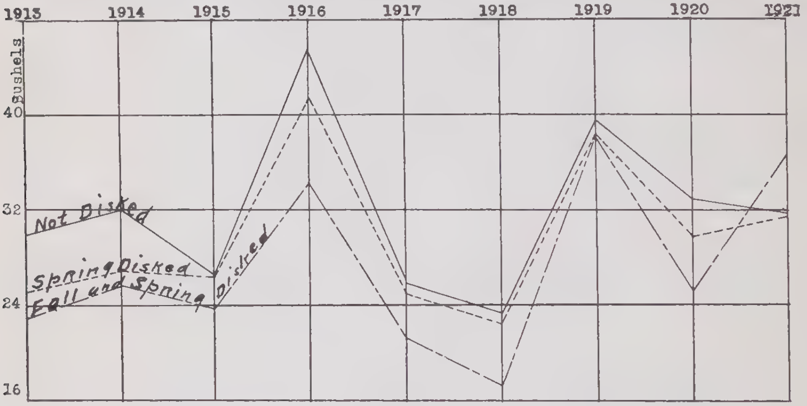

Fig. 1. Chart showing annual yields, in bushels per acre, of Turkey winter wheat after early spring plowed fallow with ground disked in the fall and spring, prior to plowing, disked in the spring and not disked, at Moro, Oregon. See Table III.

PREPARATION OF LAND BEFORE PLOWING

Fall Disking

Disking of the stubble in the fall has been advocated as a profitable practice when wheat is grown after fallow. Experiments at the Moro Station for a period of nine years indicate that disking of the stubble ground in the fall is not a good practice. Fall disking destroys stubble and often results in the blowing away of snow. Soil-mositure tests have shown that fall disking usually hinders rather than aids moisture penetration. Yields of wheat obtained after early-spring-plowed summer fallow, on which the stubble was disked in the fall, have been less on the average than yields from similar summer-fallow land not disked. The comparative yields of Turkey wheat after spring-plowed summer fallow, disked in the fall and not fall disked, at the Moro Station for the years 1913 to 1921, inclusive, are given in Table III. As is shown in this table and in Fig. 1, the annual yields of winter wheat from the fall-disked ground have been consistently less than the yields from the non-disked and spring-disked ground. Disking of stubble ground in the fall does not destroy enough of the plant growth to make spring cultivation for weed eradication unnecessary, as many weed seeds do not germinate until spring. This is also true to a certain extent of volunteer wheat.

TABLE III. ANNUAL AND AVERAGE ACRE YIELDS OF TURKEY WINTER WHEAT AFTER FALLOW PLOWED ON THREE DATES IN THE SPRING AND DISKED IN FALL AND SPRING, DISKED IN SPRING AND NOT DISKED PRIOR TO PLOWING

Year and date of plowing	Fall and spring disked	Not disked	Spring disked
	bu.	bu.	bu.
April 1—			
1913	23.0	30.0	25.1
1914	25.6	32.0	26.9
1915	23.6	26.4	26.3
1916	34.3	45.7	41.3
1917	21.2	25.7	25.0
1918	17.3	23.5	22.3
1919	38.3	39.7	38.5
1920	25.0	32.8	29.7
1921	36.5	31.7	31.3
Average	27.2	31.9	29.6
May 1—			
1913	18.5	19.0	......
1914	27.8	27.0	......
1915	27.5	24.7	......
1916	35.1	38.0	......
1917	22.3	24.7	......
1918	19.2	24.7	......
1919	35.3	30.0	......
1920	25.3	31.0	......
1921	36.7	29.8	......
Average	27.5	27.7	......
June 1—			
1913	23.0	7.3	......
1914	27.7	21.6	......
1915	23.9	20.5	......
1916	34.3	34.8	......
1917	23.1	24.7	......
1918	20.3	26.0	......
1919	32.3	19.5	......
1920	29.0	26.5	......
1921	32.5	25.2	......
Average	27.3	22.9	......

Spring Disking

When stubble is left standing through the winter a common farm practice is to disk it before plowing. The results of nine years' experiments at Moro are shown in Table III, which gives yields of Turkey wheat on land disked early in the spring, disked in the fall and spring, and not disked when plowed on three dates in the spring, early (April 1), medium early (May 1), and late (June 1). It will be noted from this table that spring disking did not increase the yields of wheat on the April plowing and that fall and spring disking did not increase the yields of wheat on the May plowing, but that fall and spring disking significantly increased the yields on the late spring plowing. It is believed that the entire benefit resulted from the spring and not from the fall disking. From these experiments it appears that spring disking of stubble, unless it is unusually tall, is unnecessary if the ground is to be plowed earlier than May 1. With tall stubble, disking may be of benefit in getting the stubble more completely covered, thereby causing less clogging of implements used to cultivate summer fallow. For late plowing, a thorough disking to kill all weeds and volunteer growth is always advisable. The annual yields of winter wheat obtained after summer-fallowed land plowed June 1 at Moro and disked and not disked are shown in Fig. 2.

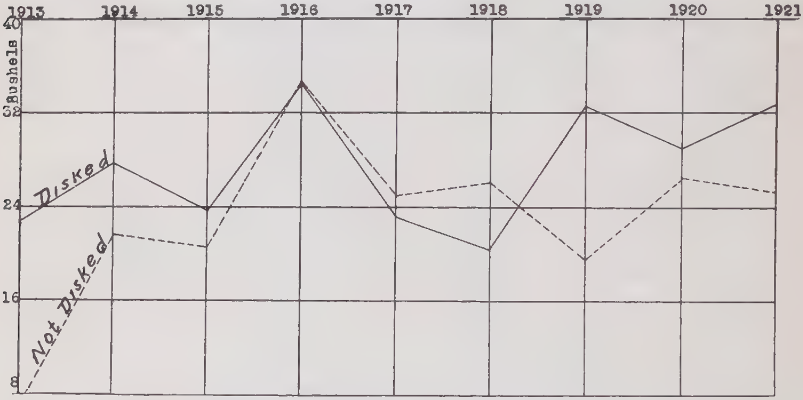

Fig. 2. Chart showing annual yields in bushels per acre of Turkey winter wheat grown after fallow plowed late in the spring with ground disked in the fall and spring before plowing and not disked, at Moro, Oregon.

Burning Stubble

No experimental data are available in Eastern Oregon on the effect of burning stubble on yields of wheat. In certain sections of heavy straw growth, stubble burning is a common practice. This method is likely to deplete the soil of needed vegetable matter and ultimately cause it to run together and be more subject to washing and gullying. Stubble in the surface soil helps to prevent blowing on the lighter soils. It is claimed by farmers that it is difficult to cultivate summer fallow on which a heavy straw growth has been turned under.

More experimental data are needed on this question. It will undoubtedly be necessary at some time to add vegetable matter in some form so as to maintain the fertility and humus content of dry farm soils. Stubble should never be burned in the fall, as the standing stubble is of considerable value in holding the snow and preventing its being drifted by the wind.

PLOWING

No extended experiments have been conducted in Eastern Oregon to determine whether any implement will take the place of the plow in the preparation of summer fallow. On light sandy soils, thorough double disking may occasionally be sufficient cultivation, but generally plowing will be found necessary in order to eradicate weeds and make a proper seed bed for wheat. Careful date and depth of plowing experiments have been conducted at the Moro Station for a number of years.

Time of Plowing

Ground has been plowed for summer fallow on two dates in the fall—early, when the ground was dry; and late, when the ground was wet; and on three dates in the spring—early (April 1), medium early (May 1), and late (June 1). On each of these dates of plowing several methods, which will be discussed later, have been used in handling the summer fallow. In Table IV are given the average yields of eight tenth-acre plots plowed on two dates in the fall and three dates in the spring. The fall-plowed land is left rough over the winter, double disked in the spring, and the fallow treated during the fallow season in the same manner as the spring-plowed land. The yields given in Table IV are average yields of eight tenth-acre plots variously cultivated. Some of these were given no cultivation, some only one harrowing, and others frequent cultivation.

TABLE IV. ANNUAL AND AVERAGE ACRE YIELDS OF TURKEY WHEAT AFTER FALLOW PLOWED ON DIFFERENT DATES AT MORO, OREGON, FOR THE YEARS 1913 TO 1921, INCLUSIVE

	Date of plowing and yield per acre				
Year	Early spring (April 1)	Medium-early spring (May 1)	Late spring (June 1)	Early fall (Dry)	Late fall (Wet)
	bu.	bu.	bu.	bu.	bu.
1913	24.3	18.5	10.6	......	......
1914	28.9	25.8	21.5	23.7	21.2
1915	25.9	25.2	21.4	22.6	22.5
1916	40.9	38.7	35.1	37.6	31.2
1917	22.3	21.4	23.1	20.6	20.3
1918	21.3	22.5	22.0	18.9	16.8
1919	37.5	31.2	21.8	31.9	32.3
1920	31.7	30.3	26.1	27.1	25.3
1921	31.5	30.6	26.0	37.8	39.2
9-year average	29.4	27.1	23.1	......	......
8-year average	30.0	28.2	24.6	27.5	26.1

It will be noted from Table IV that higher average yields of winter wheat were obtained from the early spring plowing. The yields obtained from plowing dry in the fall were on the average about equal to those obtained from plowing on May 1. The lowest yields were obtained from the late (June 1) spring plowing. A comparison of the annual yields obtained from the two dates of fall plowing and early spring plowing is shown in Fig. 3, and a comparison of the annual yields obtained from the three dates of spring plowing is shown in Fig. 4.

Spring vs. Fall Plowing. In preparing ground for summer fallow, spring plowing is the general farm practice in Eastern Oregon. The results at the Moro Station indicate that spring plowing is a better method of preparing ground for summer fallow than fall plowing. Where farmers are unable to plow their ground comparatively early in the spring, some fall plowing might be advantageously done. This is most practicable on heavy soils. As is shown in Fig. 3, the yields of winter wheat at Moro obtained after early spring plowing exceeded the yields obtained after fall plowing every year except 1921. The yields obtained that year from the fall-plowed ground were considerably higher than those obtained from spring-plowed ground. The average yield for the eight years from spring plowing, however, was 3.2 bushels an acre more than the average yield obtained from the two methods of fall plowing.

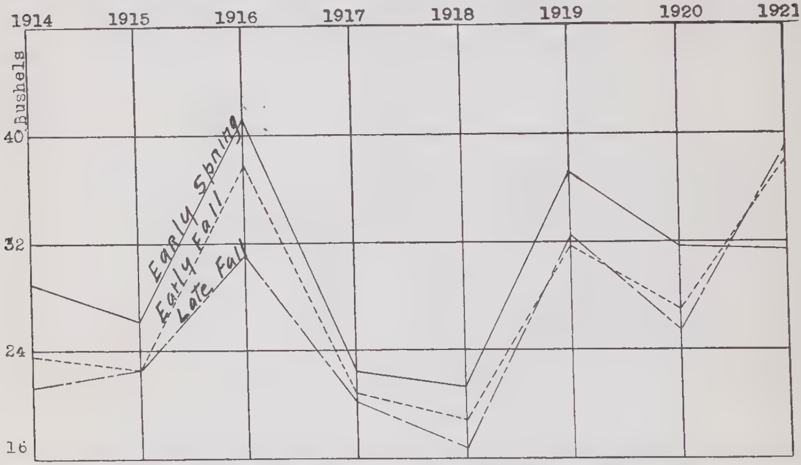

Fig. 3. Chart showing annual yields, in bushels per acre, of Turkey winter wheat grown after fallow plowed early in the fall, late in the fall, and early in the spring, at Moro, Oregon.

Of the two methods of fall plowing—early, when the ground was dry, and late, when the ground was wet—higher yields were obtained from the early or dry fall plowing. This is contrary to the general belief of many Eastern Oregon farmers, who assert that dry fall plowing is decidedly injurious. The ground at Moro is so dry and hard after harvest in the fall that plowing before the fall rains is difficult. The ground usually turns up very rough and in large lumps. This soil condition is better from the standpoint of moisture absorption than a smooth, dusty surface, as is sometimes obtained from dry fall-plowing of loose soil. A fine dust mulch of any appreciable depth in the fall is very likely to hinder the penetration of the fall and winter precipitation.

Early, Medium Early, and Late Spring Plowing. Due no doubt to the results obtained at the Moro Station, farmers in most of the dry-farming sections of Eastern Oregon are now plowing their ground considerably earlier in the spring than formerly. As is shown in Table IV and Fig. 4, the annual and average yields for the nine years obtained from the three dates of spring plowing were greatly in favor of the early spring plowing except for the two years 1917 and 1918. The apparent reason for the failure of the early-spring-plowed ground in 1917 and 1918 to produce yields higher than those obtained from a later plowing was an unusually thick stand and heavy straw and leaf growth on the early-plowed plots. This more quickly depleted the soil of its moisture and when followed by hot, dry weather after the grain headed, caused the plants to burn before the grain was ripe, resulting in shrivelled or pinched grain. On the late-plowed fallow during those two years, there was a considerably thinner stand and smaller straw growth. As a result, there was less drain on the soil moisture. This permitted the plants to mature more slowly and ripen more normally. The widest variation occurred in the year 1919, when the average yield of the April-plowed plots exceeded the yield of the June-plowed plots by nearly 20 bushels an acre. Seasonal conditions cause variations in yield from year to year. Fig. 5 shows variation in plant size due to early and late plowing.

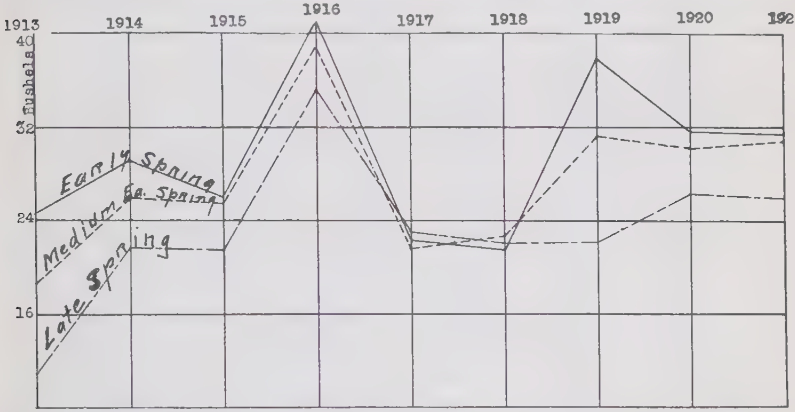

Fig. 4. Chart showing annual yields, in bushels per acre, of Turkey winter wheat grown after fallow plowed early, medium early, and late in the spring, at Moro, Oregon. Yields for each year are average yields of eight one-tenth-acre plots with soil variously cultivated during fallow season.

Time of Plowing Affects Wheat Quality. For several years investigations have been in progress at the Moro Station on the effect of time of plowing and various tillage methods on the moisture and nitrate content of the soil. These investigations have shown that time of plowing and the method of handling the summer fallow have a marked effect not only on the moisture content of the soil but on the accumulation of plant food, especially nitrate-nitrogen. These in turn influence the habit of growth of the wheat plant and the yield and quality of the wheat. Late-plowed, weedy, or poorly cultivated summer fallow usually produces soft or yellow-berried wheat, grading as Hard Winter, or Yellow Hard Winter. Early-plowed fallow if well cultivated usually produces harder and darker wheat which grades as Dark Hard Winter or occasionally Hard Winter.

Depth of Plowing

There is a general belief among farmers that depth of plowing has a marked influence on wheat yields. While different types of soil may respond differently to deep and shallow cultivation, no experimental data in the Northwest indicate that very much is to be gained from deep plowing. At the Moro Station on a silt loam soil, an experiment has been in progress since 1912 to ascertain what effect deep or shallow plowing has on yields of wheat after summer fallow. In this experiment, spring wheat was used until 1920. For 1920 and 1921, Turkey winter wheat was used. Four acres of ground were used in the experiment, two of which were in crop and two in fallow each year. Table V gives the annual and average yields of spring and winter wheat obtained on eight tenth-acre plots variously cultivated for the years 1912 to 1921, inclusive. The plowing was done each year some time during the first week in April, one acre being plowed five inches deep, the other ten

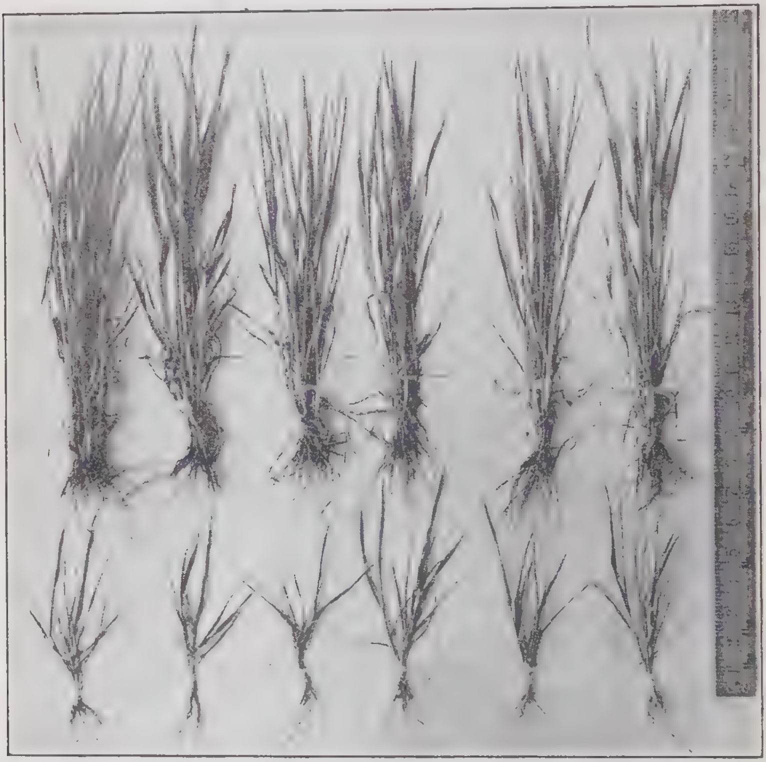

Fig. 5. Upper row, representative plants of Turkey winter wheat grown on early-plowed and well-cultivated summer fallow. Lower row, same variety sown on the same date on late spring plowed summer fallow—higher yields and better quality of winter wheat are obtained after early-plowed, properly handled summer fallow. Late-plowed summer fallow or weedy summer fallow produces low yields and poor quality wheat. Photographed April 25, 1921.

inches deep. It will be noted from Table V and Fig. 6 that the yields obtained from the ground plowed ten inches deep were slightly higher nearly every year. In two out of the nine years slightly higher yields were obtained from the shallow-plowed ground. The nine-year average yield was .9 bushel greater from deep plowing. Thus it appears that plowing deeper than six to eight inches for wheat is rarely if ever advisable. It is sometimes recommended that the depth of plowing be varied from year to year. No experiments have yet been conducted to prove definitely that this is of any advantage. It is asserted that in certain types of soil a plow sole or hard-pan is likely to form if the ground is continually plowed at the same depth. There is yet no evidence of a plow sole or hard-pan in the soil of the Moro Station plots that have not been plowed deeper than five inches for the past nine years. Heavy soils when plowed wet may be more subject to hard-pan or plow-sole formations.

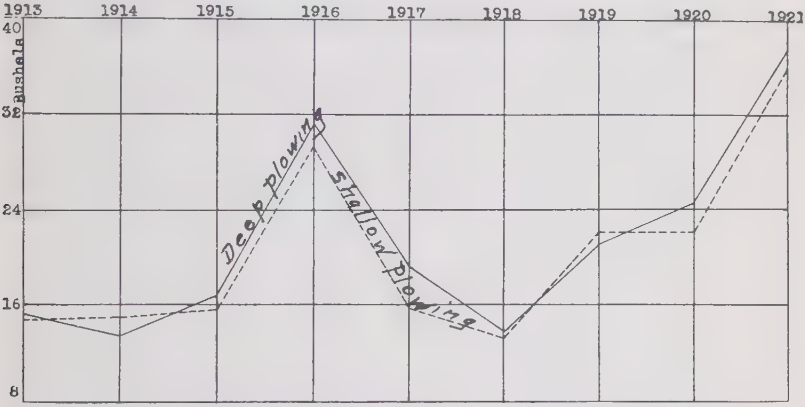

Fig. 6. Chart showing yields, in bushels per acre, of spring and winter wheat grown after fallow plowed five and ten inches deep at Moro, Oregon. Yields for each year are averages obtained from eight one-tenth acre plots with fallow ground variously cultivated. Spring wheat was grown in 1913 to 1919, inclusive, and winter wheat in 1920 and 1921.

TABLE V. ANNUAL AND AVERAGE ACRE YIELDS IN BUSHELS OF PACIFIC BLUESTEM SPRING WHEAT, EARLY BAART SPRING WHEAT, AND TURKEY WINTER WHEAT AFTER FALLOW PLOWED TEN INCHES DEEP AND FIVE INCHES DEEP AT MORO, OREGON, FOR THE YEARS 1912 AND 1914 TO 1921, INCLUSIVE*

Year	Yield per acre — Shallow plowing (5 inches)	Yield per acre — Deep plowing (10 inches)
	bu.	bu.
1912	14.9	15.2
1914	15.0	13.3
1915	15.6	16.8
1916	29.4	31.1
1917	15.9	19.1
1918	13.3	13.8
1919	22.0	21.1
1920	22.0	24.5
1921	35.8	37.4
Average	20.4	21.3

*Pacific Bluestem spring wheat was grown in 1912 and from 1914 to 1917; Early Baart spring wheat, in 1918 and 1919; and Turkey winter wheat in 1920 and 1921.

Types of Plows

There are two types of plows in general use in Eastern Oregon, the disk and the mold-board. During the years 1913 to 1919, inclusive, an experiment was conducted at the Moro Station to determine which of these plows was the better. Ground was plowed for summer fallow in the fall on two dates, early and late, with each type of plow. The yields obtained were as follows:

	Bushels per acre
Disk plow, early (dry)	24.8
Disk plow, late (wet)	23.7
Mold-board plow, early (dry)	27.2
Mold-board plow, late (wet)	24.3

The results show that for the early fall plowing the mold-board plow was the better type. The yields of the check plots, however, show that the ground on which the early-fall-plowed mold-board series was located, was considerably better than that on which the late-fall-plowed series was located, so that the increased yield obtained from the dry fall-plowed ground may not be as significant as the figures indicate. The type of plow does not markedly influence the yield, if the plowing has been properly done. The mold-board plow is the type most commonly used and is probably the better one for most Eastern Oregon soils. Often on stony ground the mold-board plow cannot be used. On certain heavy or sticky soils and in Central Oregon where there are "slick" or alkali spots, the disk plow has been found a better implement than the mold-board plow.

CULTIVATION OF SUMMER FALLOW

Many types of implements are in general use in Eastern Oregon to cultivate summer-fallowed land after plowing. Their chief purpose is to kill weeds and volunteer grains and to create a mulch to conserve moisture. The most commonly used implements for this purpose are spike-tooth harrows, spring-tooth harrows, and blade or rod weeders, of which there are several types.*

The first cultivation after plowing is usually with a spike-tooth harrow. If the soil is inclined to blow, the spring-tooth harrow is preferred because it does less pulverizing. So far as is known, immediate or delayed cultivation after plowing has little influence on wheat yields if the cultivation is not delayed too long. As a general rule early-plowed ground may be left from three to four weeks after plowing without serious moisture loss. Some farmers follow the plow immediately with a harrow. There is no objection to this and it may be of some advantage except on very light soils which are inclined to blow. Immediate tillage of such soils may have the undesirable effect of leaving them too finely pulverized. A common practice is to start harrowing the ground after plowing is completed. This usually leaves some of the ground uncultivated from five to six weeks after plowing. This is probably too long.

At the Moro Station, three methods of handling the summer fallow have been tried on several different dates of plowing and on two depths of spring plowing. The average yields obtained are shown in Table VI, and the annual yields from the three methods of cultivating fallow on early spring plowed ground are shown in Fig. 7.

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*Dry-farm tillage implements are described in Farmers' Bulletin 1047 of the U. S. Dept. of Agri., by Byron Hunter.

Good Fallow is Free From Weeds

In Table VI, the yields of wheat shown under "Frequent cultivation" were obtained after fallow harrowed twice immediately after plowing, harrowed again about thirty days later, and then kept free from weeds with a rod weeder. The fallow was usually weeded from two to four times each season. Sometimes two cultivations were sufficient, but usually three and sometimes four were necessary to keep the ground free from weeds. The ground receiving one harrowing was harrowed immediately after plowing and received no further cultivation. The weeds were hoed off by hand before they matured seed. The ground receiving no cultivation was not touched with any implement after plowing and the weeds which grew on the fallow were hoed off before they matured seed. Fig. 8 shows the superior growth on well-prepared summer fallow. Table VI shows that the yields obtained after the clean or frequently cultivated summer fallow were considerably higher for the ground plowed April 1 and also slightly higher for the ground plowed on May 1. For the ground plowed as late as June 1, the cultivation of summer fallow had no beneficial effect, the yield being practically identical for the three methods of cultivation. The results show no benefit in cultivation of dry spring-plowed ground. For spring wheat, there was only a very slight difference in favor of the frequent cultivation of the summer fallow.

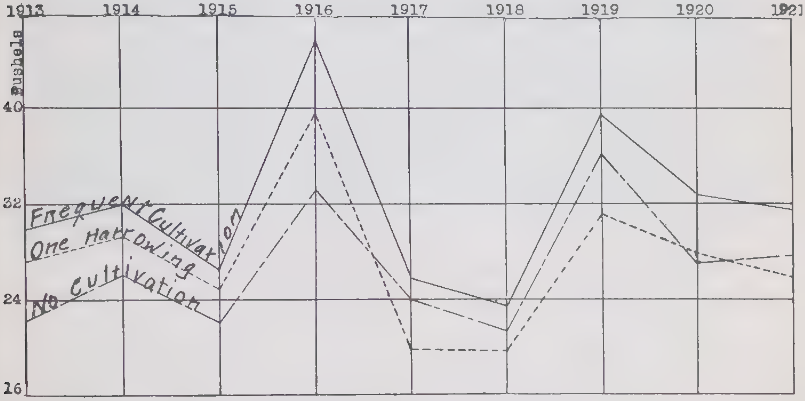

Fig. 7. Chart showing yields of Turkey winter wheat at Moro, Oregon, grown after three methods of handling summer fallow on early spring-plowed ground: frequent cultivation, one harrowing only after plowing, and no cultivation after plowing.

Farmers have found it a good practice to harrow immediately before sowing winter wheat. This operation smooths and firms the surface, making a better seed bed, which usually means a better stand of wheat. Harrowing before the drill kills many weeds that have started. Harrowing winter wheat after sowing usually is not advisable.

Hoe drills are preferred by most farmers for sowing winter wheat. This type of drill leaves the wheat in a small furrow and the ground more rough than when a disk drill is used. The small furrows hold the snow and afford some protection to the young plants, and the rough surface tends to cause less running together or crusting of the soil in the spring. These advantages would be lost if the ground were harrowed after drilling. Harrowing after drilling occasionally may be beneficial if sprouted weeds can be killed without injuring the wheat.

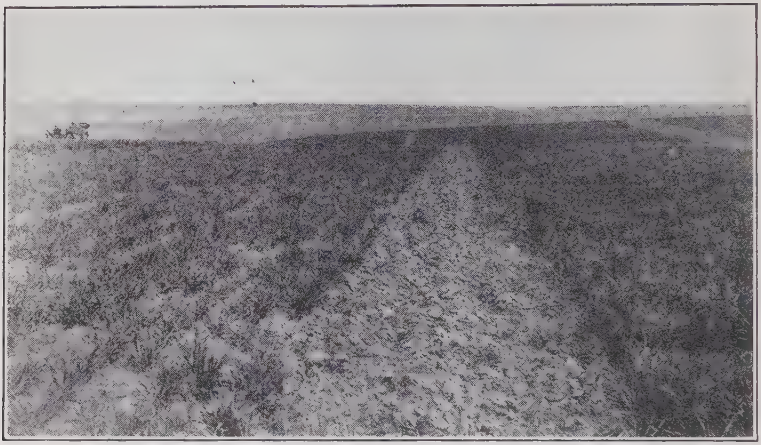

Fig. 8. Turkey winter wheat sown on poorly cultivated fallow on left and on properly cultivated summer fallow on right. Note thinner stand and less thrifty growth of plants on poorly cultivated summer fallow. Photographed April 25, 1920.

TABLE VI. AVERAGE YIELDS OF WINTER AND SPRING WHEAT AT MORO, OREGON, GROWN AFTER FALLOW GIVEN NO CULTIVATION, ONE HARROWING, AND FREQUENT CULTIVATION FOR THE YEARS 1913 TO 1921, INCLUSIVE

	Yield per acre		
Crop and date of plowing	No cultivation	One harrowing	Frequent cultivation
	bu.	bu.	bu.
Winter wheat—			
Plowed April 1	26.6	27.2	31.9
Plowed May 1	25.9	26.2	27.7
Plowed June 1	22.4	22.6	22.9
Fall plowed early	......	24.9	29.5
Fall plowed late	......	26.2	26.3
Spring wheat—			
Shallow spring plowed	19.6	19.5	20.6
Deep spring plowed	20.2	20.6	20.7

The Use of Packers

The use of surface and subsurface packers has been quite widely advocated as being beneficial in conserving moisture and in increasing wheat yields under dry-farming conditions. Experiments with these packers have been conducted at the Moro Station for a nine-year period, 1913 to 1921, inclusive. The average yields of wheat obtained are shown in Table VII, and the annual yields for the early spring-plowed plots in Fig. 9. The packers were used in different dates of plowing for summer fallow and on ground plowed at different depths for summer fallow.

Table VII shows that the subsurface packer had no significant influence on wheat yields, the average yield for the winter wheat being six pounds an acre more for the ground not packed. The surface-packed plots show a slight increase in average yield for both winter and spring wheat. For the spring wheat, the use of the Campbell packer shows a slight increase in yield per acre but not enough to be significant when the yields of the uniformly cultivated check plots are taken into consideration.

TABLE VII. AVERAGE ACRE YIELDS OF TURKEY WINTER WHEAT GROWN AFTER SUMMER FALLOW, PLOWED APRIL 1, MAY 1, AND JUNE 1, PACKED WITH SURFACE AND SUBSURFACE PACKERS FOR THE 9-YEAR PERIOD, 1913 TO 1921

Time of plowing and cultivation of fallow	Not packed	Subsurface packed	Surface packed
	bu.	bu.	bu.
April 1, clean fallow	31.7	31.1	32.2
April 1, one harrowing	27.2	28.5	......
May 1, clean fallow	27.7	28.4	28.6
May 1, one harrowing	26.2	25.9	......
June 1, clean fallow	22.9	21.7	22.4
June 1, one harrowing	22.6	22.5	......
Average	26.4	26.3	......
Pacific Bluestem and Early Baart spring wheats, and Turkey winter wheat, 1912, 1914-1921			
Shallow plowing, clean fallow	20.6	21.2	22.2
Shallow plowing, one harrowing	19.5	19.8	......
Deep plowing, clean fallow	21.6	23.7	24.9
Deep plowing, one harrowing	20.6	20.6	......
Average	20.6	21.3	......

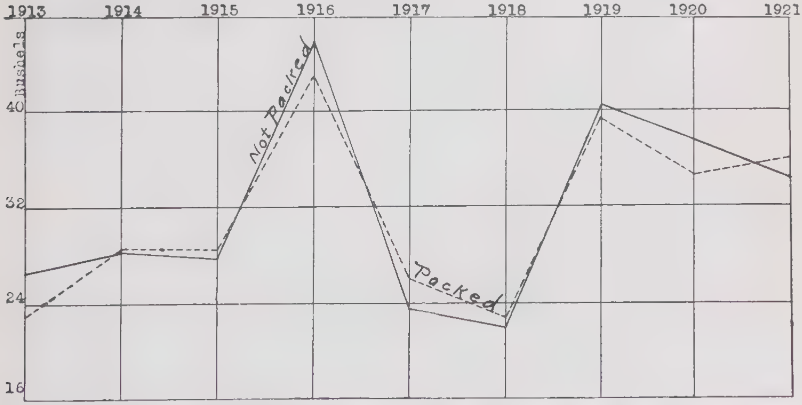

Fig. 9. Chart showing annual acre yields of winter wheat after early spring-plowed fallow packed with a subsurface packer after plowing and not packed at Moro, Oregon, for the years 1913 to 1921, inclusive.

Numerous tests have been made at Moro to determine whether the use of the subsurface packer aids in conservation of moisture. Soil samples have been taken at about thirty-day intervals during the summer-fallow season on adjacent packed and non-packed plots, and the results show that packing has practically no influence on moisture conservation. In Table VIII are given the annual and average percentages of moisture in the soil, based on dry weight, for the surface foot and for a depth of six feet, at the beginning and end of the fallow season for the years 1919 to 1921, inclusive. The data in Table VIII are for ground plowed on April 1. The average nine-year yield of these clean-fallowed plots as indicated in Table VII was 31.7 bushels for the non-packed plots and 31.1 bushels for the subsurface-packed plots.

TABLE VIII. PERCENTAGE OF MOISTURE IN THE FIRST FOOT AND TOTAL SIX FEET OF SOIL AT THE BEGINNING AND END OF THE FALLOW SEASON, PACKED WITH A SUBSURFACE PACKER AND NOT PACKED, FOR THE YEARS 1919 TO 1921 INCLUSIVE

	On April 1				On September 4			
Year	Packed 1st foot	Not packed 1st foot	Packed Total 6 ft.	Not packed Total 6 ft.	Packed 1st foot	Not packed 1st foot	Packed Total 6 ft.	Not packed Total 6 ft.
	%	%	%	%	%	%	%	%
1919	13.6	14.3	11.5	11.6	12.9	12.4	11.3	11.8
1920	12.2	12.7	10.5	10.8	8.5	8.5	10.7	10.8
1921	14.2	16.1	12.9	12.9	9.8	9.7	11.5	11.3
Average	13.3	14.4	11.6	11.8	10.4	10.2	11.2	11.3

PREPARATION OF THE SEED

All seed wheat should be thoroughly recleaned with a fanning-mill before sowing. This operation should take out all weed seeds and most of the light, cracked, or injured kernels. Plump seed especially of winter wheat is always to be preferred over shrunken seed, as the germination of plump seed generally is stronger. A better stand is more likely to be obtained if plump seed is sown. Shrunken seed is more susceptible to injury from the threshing machine and from treatment for smut.

SEED TREATMENT

No commercial variety of wheat is sufficiently resistant to bunt or stinking smut that it can be safely sown anywhere in Oregon without seed treatment. The two methods of seed treatment most widely used are the formaldehyde and copper sulfate (bluestone) treatments. Either of these treatments, if properly done, will control stinking smut in all sections of Eastern Oregon except in a few localities where there may be soil infection from wind-borne spores.

Seed wheat may be infected with smut by the smut dust or spores adhering to the seed or by wind-borne spores being deposited on the surface of summer-fallowed soil prior to sowing the wheat. In Eastern Oregon infection usually occurs from spores on the seed. These spores can be killed by seed treatment. A solution of 1 pint of commercial formaldehyde to 45 gallons of water, or 1 lb. of bluestone to 10 gallons of water followed by a dip in lime-water will effectively control stinking smut.

SEED INJURY

It has been found that seed wheat is frequently injured by either the formaldehyde or the bluestone treatments, the extent of injury to germination largely depending upon the damage done to the seed by the threshing machine. The cylinder, concave teeth, and screw conveyors of the threshing machine may crack or break the seed coat of the kernel.

This injury is not always apparent to the naked eye. The germ of the kernels so damaged may be killed or seriously injured by seed treatment. Extensive seed-treatment experiments with hand- and machine-threshed seed are reported in Oregon Agricultural College Experiment Station Bulletin 188.* As is shown in this bulletin, injury to formaldehyde-treated seed wheat is considerably lessened by an after dip or wash in clear water, and injury to bluestone-treated seed is also greatly reduced by an after dip in lime-water of the strength of one pound of lime to 10 gallons of water.

For sowing in dry ground bluestone-treated seed is best. Formaldehyde-treated seed should be sown soon after treatment and in soil moist enough to start germination promptly. A dilute solution of formaldehyde does not decrease in strength when left in an open vessel. In treating with either formaldehyde or bluestone directions should be closely followed. Failure to do this may result in a thin stand of wheat or a complete failure.

SMUT-RESISTANT WHEATS

A number of new smut-resistant winter wheats have been discovered at the Moro Station, some of which appear to be totally immune to stinking smut and others very highly resistant. It is hoped that some of these will prove to be high-yielding varieties. A variety of wheat sufficiently resistant to stinking smut so that it can be safely sown without treatment will mean the annual saving of many thousands of dollars to the farmers of Oregon.

TIME, RATE, AND DEPTH OF SOWING

WINTER WHEAT

The yields of both winter and spring wheat may be affected by time, rate, and depth of sowing. The time and depth of sowing are especially important. The stand of wheat obtained depends upon the moisture content and temperature of the soil, the time and depth of sowing, the method of treating the seed for smut, the variety, and the rate at which it is sown.

Time of Sowing

In many sections of Eastern Oregon, the fall rains do not come early enough to make conditions favorable for sowing winter wheat. Elaborate experiments at the Moro Station indicate that if there is enough moisture in the ground to insure prompt germination, the highest yields of winter wheat are usually obtained from sowing it some time between the middle of September and the middle of October. In Table IX are given the yields of Turkey winter wheat sown at varying rates from 2 to 8 pecks an acre, inclusive, on five dates in the fall, for the years 1916 to 1921, inclusive. The highest average yields for the six years were obtained from the two earliest dates of sowing, September 17 and October 2. The average yield obtained from the third date, October 14, was only slightly lower than that obtained from the earlier dates. The average yields obtained from the two later dates of sowing, October 30 and November 19, were much less than those obtained from the three earlier dates, indicating that winter wheat to get maximum yields should be sown, in the location of Moro, before October 30. This date will vary for different localities, earlier seeding being preferable at higher elevations. To get maximum yields of winter wheat, it is necessary to have it up well before the cold winter weather begins.

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*The Wheat Bunt Problem in Oregon, Oregon Agric. Col. Exp. Sta. Bulletin No. 188, by D. E. Stephens and H. M. Woolman.

Sowing in the Dust

Experiments at Moro and the experience of farmers show that there is little if anything to be gained by sowing winter wheat in ground so dry that germination will not take place promptly. Wheat that has been treated with formaldehyde if sown in dry ground or "in the dust" may rot before it emerges. It has been found that the bluestone treatment is more satisfactory if wheat is to be sown in dry ground. Treated seed should be dry before being sown in the dust. During certain seasons, winter wheat may have to be sown in dry ground if sown at all. Under such conditions, seeding should be done at least thirty days before freezing weather is expected and more seed should be used.

In the experiments to determine the best rate and date of sowing winter wheat, as reported in Table IX, there were two years of the six when winter wheat sown in September and early October did not come up until after the fall rains. During two of the years, therefore, the first three dates of sowing came up at the same time. For the other four years, emergence took place within ten to twenty days after sowing the wheat. Winter wheat, if sown late in October or in November at Moro frequently will not come up until spring.

Amount to Sow

As is shown in Table IX, there was not a wide variation in the average yields obtained from the different rates of sowing Turkey wheat. The rate shown in the table is for seed treated with formaldehyde. Wheat after being treated or dipped in water always increases in volume from 20 to 30 percent and does not run through the drill as readily as dry seed. In terms of dry seed per acre, the amount indicated in the table should be reduced by about one-fourth.

The highest net average yield was obtained from sowing wheat with the drill set to sow five pecks of treated seed to the acre or approximately one bushel of dry seed. Experience of farmers in the Columbia Basin of Oregon indicates that this is usually about the best rate to sow winter wheat except on the shallower soils, on which thinner seeding is desirable. Many farmers use the same rate on deep and shallow parts of the field and attribute the early burning on shallow ground to frost.

Conditions Affecting Rate of Sowing

The rate of sowing must be varied according to the time of sowing, condition of the seed bed, method of handling summer fallow, and the viability of the seed. Certain varieties also require thicker seeding than others, because of larger seed or less stooling. Seed sown early when the ground is warm and with sufficient moisture for prompt germination can be sown at a thinner rate than when sown in dry ground or late in the season when the ground is cold. A finely pulverized and well-packed seed bed will not require as thick a rate of seeding as a seed bed that is rough or too loose. Early-plowed and well-kept fallow does not require as thick sowing as late-plowed or poorly handled fallow. Wheat does not stool or tiller well on improperly handled fallow, because of the lack in such fallow of available plant foods, especially nitrate-nitrogen. A thin stand of wheat on early plowed and well-tilled fallow may be partly or wholly made up by extra stooling or tillering. If the wheat has been injured by seed treatment, as can be ascertained by a germination test, it should be sown more thickly than uninjured seed. Changing from copper sulfate to formaldehyde for seeding in damp soil or changing from either to copper carbonate is likely to result in too thick stands because of less seed injury.

Sow Wheat Shallow

Experiments at Moro and elsewhere have indicated that winter wheat should be sown shallow. This is especially true of late seeding when the ground is cold. If the wheat is planted deep in cold ground, it is almost sure to rot. Occasionally winter wheat may be safely sown three or four inches deep if sown early in well-cultivated summer fallow. This may sometimes be necessary to get the seed below the dry mulch into moist soil. In such cases more seed should be used, as many sprouts will not reach the surface. Generally it has been found safer not to sow wheat more than one to one and a half inches deep. Late fall sowing should always be shallow.

TABLE IX. AVERAGE ACRE YIELD IN BUSHELS OF TURKEY WINTER WHEAT IN THE RATE OF SEEDING EXPERIMENT AT MORO, OREGON, DURING THE SIX-YEAR PERIOD, 1916 TO 1921, INCLUSIVE

Rate in pecks	Average date of sowing						
	Sept. 17	Oct. 2	Oct. 14	Oct. 30	Nov. 19	Average	Net* average
2	29.9	34.3	31.6	22.1	19.4	27.5	27.0
3	35.8	33.9	32.5	22.6	20.1	29.0	28.2
4	32.7	33.0	32.1	26.6	22.3	29.3	28.3
5	34.5	37.2	31.1	26.6	23.9	30.7	29.4
6	33.9	32.5	30.7	26.8	23.9	29.6	28.1
7	35.5	32.7	32.1	28.2	24.0	30.5	28.7
8	34.6	30.4	33.1	27.8	23.5	29.9	27.9
Average	33.8	33.4	31.9	25.8	22.4	29.5	28.2

*Average yield, less quantity sown.

SPRING WHEAT

Extensive tests at the Moro Station and results obtained by farmers in Eastern Oregon indicate that spring wheat should be sown as early in the spring as possible. The rate of sowing depends upon the variety, time of sowing, and the condition of the seed bed. For most varieties, the sowing of from 4 to 5 pecks an acre has been found to give best results. Some large-kerneled varieties like Early Baart require thicker seeding. The rate of seeding also should be varied in different sections depending upon the annual precipitation and the depth of soil. For shallow soil or for locations with light rainfall, thinner seeding is advisable.

CULTIVATION OF THE GROWING CROP

Winter wheat is sometimes harrowed in the spring in the Columbia Basin. Extensive experiments to ascertain whether this practice is beneficial or injurious have been carried on at Moro for nine years. The average yields obtained in these experiments are shown in Table X. The annual yields are shown in Fig. 10. As will be seen from Table X, the experiment was repeated five times on different methods of plowing. Where one plot was harrowed, an adjacent plot was not harrowed. The average yields for the nine-year period show that the acre yield of winter wheat was reduced one bushel by harrowing in the spring. Fig. 10 shows that there was one year (1919) when an increase in yield of winter wheat was obtained by spring harrowing. There were also two other years, 1915 and 1921, when a slight increase in yield was obtained. There may be certain soil types and conditions when harrowing winter wheat is justified, but the results of experiments in dry-land sections, as well as results by farmers, indicate that the practice more frequently reduces rather than increases yields of winter wheat.

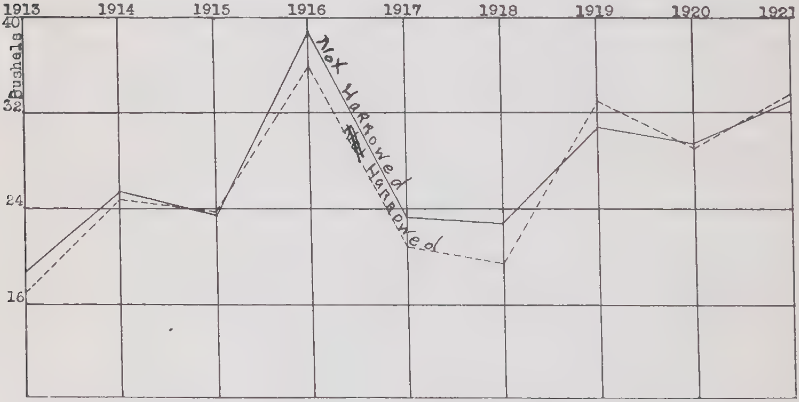

Fig. 10. Chart showing acre yields in bushels of winter wheat harrowed in the spring and not harrowed at Moro, Oregon, for the years 1913 to 1921, inclusive.

The purposes to be gained in harrowing winter wheat are (1) the killing of weeds and (2) the breaking of the crust and forming of a mulch to conserve moisture. It is not often that very many weeds can be killed by spring harrowing and as a general rule the mulch created by harrowing is of little benefit in moisture conservation. Harrowing crusted land often sets back the ripening of the crop. This may be due to covering the plants with clods and also to breaking of roots. If winter wheat is harrowed in the spring, it should be when the soil is not badly crusted or when the crust has been softened by rain. It is never advisable to harrow or cultivate spring-sown grain after emergence. Spring-sown grain may frequently be safely harrowed five or six days after sowing but harrowing after the grain is up is likely seriously to reduce the stands by tearing out the young plants.

TABLE X. AVERAGE ACRE YIELDS IN BUSHELS OF TURKEY WINTER WHEAT HARROWED IN THE SPRING AND NOT HARROWED AT MORO, OREGON, FOR THE YEARS 1913 TO 1921, INCLUSIVE

Date and method of plowing	Yield per acre Harrowed	Yield per acre Not harrowed
	bu.	bu.
Plowed April 1	30.1	31.9
Plowed May 1	26.8	27.7
Plowed June 1	22.8	22.9
Plowed in fall, early (dry)	28.1	29.5
Plowed in fall, late (wet)	25.5	26.3
Average	26.6	27.6

WHEAT VARIETIES

In the economic production of wheat, a variety which will give maximum yields with no additional expense, is greatly to be desired. There is no doubt that wheat yields can be greatly increased in Eastern Oregon by the growing of better adapted varieties.

A wheat survey of Eastern Oregon shows that there are commercially grown five varieties of hard red winter; eight of soft red winter; two of hard red spring; eleven of common white; twelve of white club; and three miscellaneous kinds of wheat—a total of forty-one varieties, the majority of which are inferior in yield, quality or both.

OREGON GROWS TOO MANY VARIETIES

The elimination of all varieties of hard, red spring and the replacing of them with Federation, or Hard Federation, the dropping of all the miscellaneous and practically all soft red winter varieties and the reduction of the numbers in all other classes will give larger average yields and decrease the amount of mixed wheat.

STANDARD VARIETIES

Turkey and Hybrid 128 will take care of most of the present winter wheat needs. Hard Federation and Federation will, when seed is available, be best for general spring planting. Until Federation and Hard Federation are more abundant, Early Baart will be generally used and results show it to be a superior wheat in high, dry sections of southeastern Oregon.

Other varieties in most cases mean reduced yields. The dropping out of culture of all varieties except these five and possibly Jenkin Club and Triplet for limited areas, will mean better returns for Eastern Oregon wheat farmers. Standard varieties without mixture give the highest yields and bring the best prices.

Extensive experiments have been conducted at the experiment stations at Moro in Sherman county and at Burns in Harney county to determine the highest-yielding winter and spring wheat varieties for Eastern Oregon.

WINTER WHEAT

At Moro many hundreds of wheat varieties have been grown in short rows and in larger field plots and several varieties have been discovered that have given higher acre yields than the varieties formerly grown in this section. The winter wheat varieties which have been tried in field plots for two years or more are listed alphabetically in Table XI with their annual and average acre yields. These varieties have been carefully tried under comparable conditions. Those that were not especially promising because of low yield, weak straw, or shattering, after a two years' trial were discarded. A few commercial varieties that gave comparatively low yields, like Fortyfold, have been continued in the varietal trials. All of them were grown after well-prepared summer fallow. There are yields for only three varieties in 1913. Because of the inability to get stands of many of the varieties that year, an accurate comparison of most of them was not obtained. The varieties in 1912 were grown in single tenth-acre plots and from 1914 to 1921 inclusive, in triplicate twentieth-acre plots.

In the last column of Table XI, the yield of each variety is expressed in the percentage of the yield of the local Turkey wheat. The local Turkey wheat was the Turkey variety grown in the vicinity of Moro at the time of the establishment of the Station. As will be seen from this table, several varieties of wheat, which have been in the trial for five or more years, have exceeded the local Turkey wheat in yield by from 5 to 9 percent. Several of these are of the Turkey or Crimean group, hard red winter wheats that have proved very successful in all dry-land sections of the United States. The Kharkov variety, C. I. 1442, which has on the average yielded 8 percent more than the local Turkey, has been distributed from the Moro Station and is now being widely grown throughout Eastern Oregon.

Description of Leading Varieties

The Turkey or Crimean Wheats. Turkey wheat was introduced into the Columbia Basin of Oregon by farmers about 1906 or 1907. On account of its high yield, winter-hardiness, good quality, and smut-resistance, the variety rapidly gained in popularity until the Turkey and allied varieties are now the leading winter wheats grown in Eastern Oregon. There were more than 150,000 acres of Turkey and related varieties grown in Eastern Oregon in 1921. According to a varietal survey made by the Office of Cereal Investigations of the United States Department of Agriculture, 29 percent of all the wheat produced in the United States in 1919 was Turkey or some strain of Turkey. Considerable work has been done with this variety by experiment stations throughout the United States, and many improved strains have been produced.

Kharkov (C. I. 1442). This variety is a high yielding Turkey wheat. At the Moro Station for a ten-year period, it has exceeded the yield of the local Turkey wheat by 8 percent. Kharkov was originally introduced into the United States from Russia by the United States Department of Agriculture.

Argentine (C. I. 1569). This is another wheat of the Turkey type that has been a high yielder at the Moro Station. Its average yield for a ten-year period has been 8 percent higher than that of local Turkey.

Turkey (C. I. 1571). This is a strain of Turkey wheat that at the Moro Station during a ten-year period has exceeded the yield of the local Turkey 7 percent. A selection from this wheat which is highly resistant to stinking smut is being increased and tested for yield.

TABLE XI. ANNUAL AND AVERAGE YIELDS, IN BUSHELS PER ACRE, OF WINTER WHEAT VARIETIES AT MORO, OREGON, IN THE YEARS 1912 TO 1921, INCLUSIVE, WITH THE YIELD OF EACH VARIETY EXPRESSED IN THE PERCENTAGE YIELD OF THE LOCAL TURKEY VARIETY

C. I. No.	Variety	Yield per acre 1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	Total	Average	Percent of local Turkey
		bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	%
6682	Alaska x Jones Fife	......	......	......	......	......	......	......	......	......	38.5	......	38.5	......
2979	Alberta Red	19.8	24.5	24.2	25.5	54.6	23.9	25.6	39.0	32.2	39.6	308.9	30.9	106
5971	Alberta Red	......	......	......	......	......	......	......	......	......	35.3	......	35.3	......
1569	Argentine	23.1	......	26.1	25.0	53.6	25.3	25.1	37.5	32.2	40.6	288.5	32.1	108
1355	Armavir	30.5	18.4	19.5	21.0	53.0	24.3	22.3	......	......	......	189.0	27.0	101
1562	Bacska	20.2	......	25.9	......	......	......	......	......	......	......	46.1	23.0	128
1544	Beloglina	12.3	......	17.0	......	......	......	......	......	......	......	29.3	14.7	82
2239	Beloglina	12.9	......	26.0	23.4	52.3	23.0	22.4	37.8	......	......	197.8	28.3	97
4251	Blackhull	......	......	......	......	......	......	......	......	35.3	40.1	75.4	37.7	103
1432	Crimean	14.5	......	21.0	......	......	......	......	......	......	......	35.5	17.7	99
1437	Crimean	20.2	......	26.7	19.9	50.7	25.5	25.5	36.3	......	......	204.8	29.2	105
4155	Dale Gloria	......	......	12.3	29.0	40.0	......	......	......	......	......	81.3	27.1	92
1395-2	Diehl Mediterranean	23.1	......	19.0	......	......	......	......	......	......	......	42.1	21.0	117
4156	Fortyfold	17.5	21.6	19.7	26.5	38.0	21.8	25.9	26.2	25.9	28.1	251.2	25.0	86
6681	Fortyfold x Little Club (173)	......	......	......	......	......	......	......	32.0	32.0	41.9	105.9	35.3	96
1438	Ghirka Winter	10.6	......	20.8	17.1	49.8	22.5	22.2	......	......	......	143.0	23.8	85
2996	Goldcoin	17.5	......	20.0	......	......	......	......	......	......	......	37.5	18.8	105
4511	Hybrid 123	......	......	......	33.5	54.1	23.6	25.2	40.7	32.0	43.5	252.6	36.1	109
4512	Hybrid 128	......	......	......	......	......	......	26.5	40.6	36.8	43.0	146.9	36.7	107
4468	Jones Fife	......	......	......	......	......	......	......	22.2	31.7	28.4	82.3	27.4	75
5146	Kanred	......	......	......	......	......	20.8	24.1	38.4	32.7	40.0	156.0	31.2	98
1442	Kharkov	27.6	......	24.0	21.3	52.3	24.3	26.2	40.0	33.2	40.1	289.0	32.1	108
5549	Kharkov	......	......	......	......	......	......	......	38.2	31.8	......	70.0	35.0	100
2997	Kofod	16.0	......	15.4	......	......	......	......	......	......	......	31.4	15.7	88
6250	Nebraska 60	......	......	......	......	......	......	......	......	33.0	41.9	74.9	37.5	86
4068	Prohibition	27.8	......	20.5	24.6	42.8	21.1	......	......	......	......	136.8	27.4	105
1915	Purple Straw	......	20.0	24.5	18.6	......	......	......	......	......	......	63.1	21.0	99
4069	Red Chaff	26.0	......	16.5	......	......	......	......	......	......	......	42.5	21.2	118
6553	Red Hussar	......	......	......	......	......	......	......	......	......	33.0	......	33.0	......
2942	Rieti	22.6	......	22.9	......	......	......	......	......	......	......	45.5	22.7	127
5544	Super	......	......	......	......	......	......	......	25.7	32.7	30.3	88.7	29.6	81
1561	Theiss	13.6	......	27.5	24.7	54.0	22.2	22.6	38.1	......	......	202.7	29.0	104
1539	Torgova	10.6	......	26.3	19.2	......	......	......	......	......	......	56.1	18.7	98
5408	Triplet	......	......	......	......	......	28.8	26.7	37.1	35.7	38.7	167.0	33.4	105
1571	Turkey	14.6	......	29.0	26.5	53.4	23.6	25.4	41.5	32.5	40.3	286.8	31.9	107
1558	Turkey	17.6	24.0	22.4	20.6	55.0	26.0	23.6	38.1	33.0	38.4	298.7	29.9	103
1756	Turkey	22.0	......	17.3	21.7	55.0	24.6	25.1	38.4	......	......	204.1	29.2	100
2998	Turkey	12.5	......	17.2	26.5	49.5	25.3	26.8	42.0	33.0	......	232.8	29.1	98
4429	Turkey (Local)	13.3	......	22.5	21.3	50.8	22.3	27.3	36.6	33.5	39.9	267.5	29.7	100
1563	Weissenberg	15.0	......	26.0	20.9	......	......	......	......	......	......	61.9	20.6	108
2907	Zimmerman	23.5	......	21.7	......	......	......	......	......	......	......	45.2	22.6	126

Kanred (C. I. 5146). This is a pure-line selection from Crimean, made by the Kansas Experiment Station several years ago. It has proved to be a much higher yielding wheat in parts of Kansas and other sections of the Great Plains region. During the time it has been in the trial at the Moro Station, it has not equalled the yield of the local Turkey and several other varieties.

The Washington Hybrid Wheats. Several of the Washington Experiment Station's hybrid wheat varieties are grown commercially in Eastern Oregon. These in the order of their total production are Hybrid 128, Hybrid 63, Hybrid 143, Triplet, and Hybrid 123. All these hybrid wheat varieties are very susceptible to stinking smut.

Hybrid 128. This variety, often called White Hybrid, is a cross between Jones Fife and Little Club. It has been in the varietal trials at Moro for a four-year period and during that time has exceeded the yield of local Turkey 7 percent. Unlike Hybrid 123, it is a true winter wheat and will not mature if spring planted. It ripens a little later than Hybrid 123. It is a club wheat with soft white kernels. It has proved to be a very popular variety of wheat in Umatilla county on account of its stiff straw and its high yield under favorable conditions. In that county more than 60 percent of the wheat acreage is sown to Hybrid 128, with a usual annual production of from three to four million bushels of that one variety. The variety is recommended by Schafer, Gaines, and Barbee* as being better suited to general culture in the State of Washington than any of the other commercially grown hybrid varieties. Its quality is reported to be better than that of Hybrid 123, but when grown at Moro the milling quality has been inferior to that of Hybrid 123.

Hybrid 63. The production of Hybrid 63, or "Turkey Hybrid," is confined chiefly to Wasco county, where farmers report good yields from the variety when grown as a winter wheat. Because of its inability to survive the winter at Moro, it has not been included in the winter-wheat varietal trials there. It was grown for two years as a spring wheat and discarded because of its low yield. It is a white-kerneled club wheat produced by crossing Turkey and Little Club.

Triplet. This is one of the more recent hybrids produced by the Washington Agricultural Experiment Station. In its production, three wheats were used, Turkey, Jones Fife, and Little Club. The head and kernel characters more nearly resemble those of Jones Fife, being a red-kerneled, beardless, velvet-chaff wheat. It has a shorter straw than Jones Fife and matures earlier. It has exceeded the yield of the local Turkey at Moro for a five-year period by 5 percent. The variety, as is shown by the milling and baking data reported elsewhere in this bulletin, is a better milling wheat than Jones Fife and nearly equal to Turkey.

Hybrid 123 (Red Hybrid). This is a red-kerneled club wheat which is also a cross between Jones Fife and Little Club. During the seven-year period in which it has been in the varietal trial at Moro, it has exceeded the yield of the local Turkey wheat 9 percent. The variety is a high yielding dry-land wheat but wheat buyers and millers maintain that it is not up to the standard of other wheats in milling quality. The results of baking and milling trials, discussed elsewhere, show that the variety when grown after well-kept summer fallow at Moro produces a fairly satisfactory milling wheat.

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*Wheat Production as Influenced by Variety, Time of Seeding, and Source of Seed, by E. G. Schafer, E. F. Gaines, and O. E. Barbee, Washington Station Bulletin No. 159.

Other Winter Wheat Varieties. *Fortyfold.* This variety, correctly named Goldcoin, has been grown in Eastern Oregon for a long time. It is still quite extensively grown, but is now chiefly found at high elevations or on shallow soils. On account of its poor milling quality and its susceptibility to shattering and to stinking smut, the variety can probably be replaced very profitably by other higher yielding and much more desirable winter wheats. The annual shattering loss from this variety is probably two to three bushels an acre on dry land.

Red Chaff. This variety, which is probably a field hybrid between a club wheat and Fortyfold, is a commercial variety in Umatilla and Union counties. The variety is a soft, white, club wheat with brown chaff. It has not proved winter-hardy at Moro and therefore has not been continued in the winter wheat varietal trials. It can probably be replaced as a winter variety by a hardier and higher-yielding type. As a spring wheat, it is too late maturing and can be replaced by one of the Federation wheats or Early Baart.

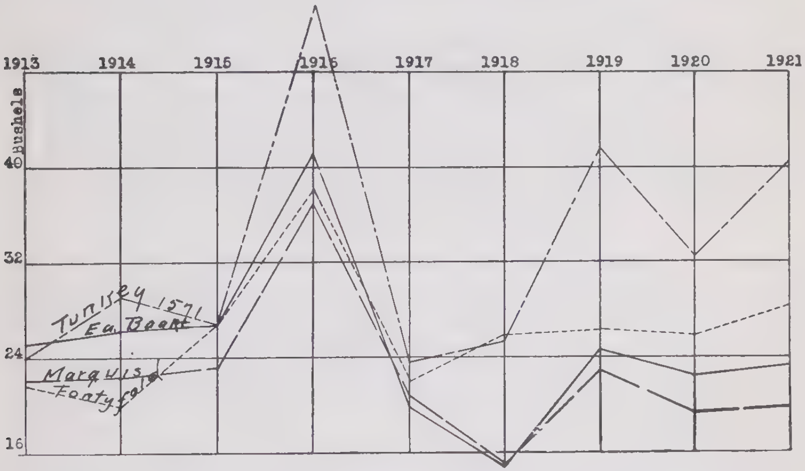

Fig. 11. Chart showing annual acre yields in bushels of two winter wheats (Turkey and Fortyfold) and two spring wheats (Early Baart and Marquis) at Moro, Oregon, for the nine years 1913 to 1921, inclusive.

Jenkin. Several thousand acres of fall-sown Jenkin or Jenkins Club wheat are grown in Umatilla county. This variety, a late-maturing spring wheat, has not proved winter-hardy at Moro, and frequently winter kills in the Blue Mountain section. Careful trials should be conducted to ascertain whether this wheat cannot be profitably replaced in Umatilla county with a hardier and higher yielding variety. This variety is generally recognized as the poorest in quality of the white club wheats.

SPRING WHEAT

Although winter wheat usually outyields spring wheat in most sections of Eastern Oregon, considerable spring wheat will always be grown in this region. After failure of winter wheat or when fall weather does not permit extensive seeding, spring varieties are grown. In localities where winter wheat does not come up well in the fall or in high altitudes where winter wheat is killed by early frosts, spring wheat is better.

In Fig. 11 are shown the annual yields of two winter wheats, Turkey, C. I. 1571, and Fortyfold, and the yields of two spring wheats, Early Baart and Marquis, for the years 1913 to 1921, inclusive. The chart shows that in four of the nine years, there was not much difference in the yields of the winter and spring wheats, but that in the other five years the winter wheats considerably outyielded the spring wheats.

Hundreds of varieties of spring wheats have been tried at the Moro Station in rows and in field plots. Those that have been grown two years or longer in field plots under comparable conditions are listed alphabetically in Table XII, with the percentage of yield expressed in terms of that of the Early Baart variety.

It will be noted from this table that there are several varieties in the list that have been grown for several years which have exceeded the yield of the Early Baart variety from 10 to 23 percent. Three of these wheats, Federation, Hard Federation, and White Federation, introductions from Australia, have exceeded the yield of the Early Baart variety for each of the four years during which they have been grown.

Description of Leading Varieties

Pacific Bluestem. This variety was formerly the standard spring wheat grown in Eastern Oregon. It is a late-maturing, beardless, white wheat with a good reputation as a milling wheat. On the dry lands, it has during recent years been largely replaced by the Early Baart variety. At the Moro Station, Early Baart has exceeded the yield of Pacific Bluestem 10 percent.

Early Baart. This popular dry-land wheat was introduced from Australia by the United States Department of Agriculture. It is bearded, with soft to semi-hard, large white kernels. It is adapted to sections of very light rainfall. It is generally considered superior to Pacific Bluestem for milling. The straw is rather weak. On account of its large kernels and its susceptibility to injury by the threshing machine and by treatment for smut, it must be sown at a thicker rate than most other spring-wheat varieties.

Bobs. This variety, an introduction from Australia, has been grown at Moro for nine years. It is an early-maturing, beardless white wheat of exceptionally good milling quality. For the nine-year period, it has exceeded the yield of Early Baart 7 percent. The variety is not commercially grown in Oregon.

Hard Federation. This variety is an early-maturing, beardless brown chaff wheat with short, hard, white kernels. In preliminary trials, this

TABLE XII. ANNUAL AND AVERAGE YIELDS IN BUSHELS PER ACRE OF SPRING WHEAT VARIETIES AT MORO, OREGON, FOR THE YEARS 1912 TO 1921, INCLUSIVE, WITH THE YIELD OF EACH VARIETY EXPRESSED IN THE PERCENTAGE YIELD OF THE EARLY BAART VARIETY

C. I. No.	Variety	Yield per acre 1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	Total	Average	Percent of Early Baart
		bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	bu.	%
......	Alaska	......	13.6	15.0	......	......	......	......	......	......	......	28.6	14.3	56
2407	Aulieata	......	23.0	22.9	20.2	42.0	......	......	......	......	......	108.1	27.0	91
2511-2	Ble Noir	7.5	18.0	18.3	23.6	34.6	13.5	16.0	20.0	......	......	151.5	18.9	77
4067	Bluestem (Pacific)	21.3	19.4	20.9	24.0	37.3	17.5	13.0	23.7	18.2	21.5	216.8	21.7	90
2826-1	Bobs	......	24.2	24.7	25.4	45.5	23.0	18.5	26.4	24.0	26.2	237.9	26.5	107
2227	Chul	12.9	......	21.5	20.2	39.1	21.7	15.7	......	......	......	131.1	21.9	89
4155	Dale Gloria	8.6	18.3	18.3	......	......	......	......	......	......	......	45.2	15.1	65
3663	Dicklow	......	......	......	......	......	13.0	14.7	......	......	......	27.7	13.8	79
1697	Early Baart	19.0	25.0	26.0	26.6	40.9	19.8	14.9	24.2	22.4	23.5	242.3	24.2	100
1697-1	Early Baart	......	......	......	......	......	......	......	......	24.0	24.0	48.0	24.0	105
4734	Federation	......	......	......	......	......	......	21.0	28.7	24.5	29.9	104.1	26.0	122
1596	Fretes	......	......	......	25.7	35.1	20.2	......	......	......	......	81.0	27.0	93
2398	Galgalos	12.7	......	......	......	......	20.7	18.3	19.0	......	......	70.7	17.7	90
1517	Ghirka	......	19.6	16.2	26.1	32.5	......	......	......	......	......	94.4	23.8	77
4733	Hard Federation	......	......	......	......	......	......	21.3	28.7	25.9	29.0	104.9	26.2	123
4980	Hard Federation	......	......	......	......	......	......	......	26.3	23.5	......	49.8	24.9	107
2669	Heines Square Head	......	21.6	22.5	23.6	39.8	......	......	......	......	......	107.5	26.9	91
4157	Hybrid 63	15.5	20.6	15.3	......	......	......	......	......	......	......	51.4	17.1	73
5025	Hybrid 108	8.6	16.0	......	......	......	......	......	......	......	......	24.6	12.3	56
2200-1	Karun	......	24.0	25.4	29.4	37.9	24.0	18.3	23.4	......	......	182.4	26.1	103
2203-2	Koola	......	25.8	24.2	33.2	44.8	23.7	17.9	26.4	......	......	196.0	28.0	111
1440	Kubanka	16.2	13.6	15.0	......	......	13.7	13.3	15.5	......	......	87.3	14.2	66
1516	Kubanka	......	16.0	21.5	18.0	29.5	15.3	13.3	......	......	......	113.6	18.9	74
4066	Little Club	22.6	19.6	19.2	26.0	42.3	17.8	18.0	23.0	20.0	22.2	230.7	23.0	95
4158	Marquis	......	22.1	22.5	23.1	37.0	20.8	15.0	22.7	19.2	19.7	202.1	22.5	91
6225	Red Bobs	......	......	......	......	......	......	......	......	15.0	22.0	37.0	18.5	80
2793	Rieti	......	21.3	19.5	24.9	29.9	......	......	......	......	......	95.6	23.9	81
?346-1-1	Saumur	......	......	......	......	47.5	25.0	14.7	......	......	......	132.9	26.6	104
3036	Sonora	4.6	15.3	20.5	24.7	38.6	18.0	18.4	23.7	20.5	......	184.3	20.5	85
2495	Talimka	......	27.5	23.0	25.9	44.5	24.7	18.3	25.2		......	189.1	27.0	107
4981	White Federation	......	......	......	......	......	......	......	28.3	23.7	27.7	79.7	26.6	114
2404	Yantagbay	19.0	21.3	19.4	25.2	42.4	22.7	14.0	22.2	......	......	186.2	23.3	95
2799	Zacatas	......	19.6	21.0	25.2	37.2	......	......	......	......	......	103.0	25.7	87

and the other Federation wheats at the Moro Station* showed up so well that they were increased and put in the regular field varietal trials. For the four years, 1918 to 1921, inclusive, during which this wheat has been in field trials, it has every year exceeded the yield of Early Baart and averaged 23 percent higher. The variety is of excellent milling quality, being superior to either Early Baart or Pacific Bluestem in this respect, as is shown in Table XIII. Considerable Hard Federation wheat has been distributed from the Moro Station. The Station's results and reports from farmers who grew it indicate that Hard Federation is the best dry-land spring wheat except for sections of extremely light rainfall.

Federation. This is a beardless, white wheat with brown chaff, from which Hard Federation was selected. It matures a little later than Hard Federation and has a slightly longer head. The kernels are softer than those of Hard Federation and the wheat is not of as good milling quality, though about equal to Early Baart. It has proved to be an exceptionally high yielding wheat under irrigation at the Burns Station in Oregon and at the Aberdeen Station in Southern Idaho.

Marquis. This is a hybrid wheat produced at the Central Experimental Farm at Ottawa, Canada, and is one of the most widely grown spring wheats in the United States. It is one of the best commercially grown milling wheats. At the Moro Station it has yielded 9 percent less than Early Baart for a nine-year period. It is grown extensively in some sections of Eastern Oregon. It can profitably be replaced by either Hard Federation or Early Baart on the dry-land areas of the Northwest.

MILLING AND BAKING INVESTIGATIONS

Through a cooperative arrangement with the Office of Cereal Investigations of the Bureau of Plant Industry and the milling and baking laboratories of the Bureau of Markets of the United States Department of Agriculture, milling and baking trials have been conducted for several years with both winter and spring wheats grown at the Moro Station. Several of these wheats have also been milled from time to time by the Portland Flouring Mills, Portland, Oregon. From unpublished data thus obtained Table XIII has been prepared, giving a summary of some of the data obtained in these investigations with five varieties of winter and five varieties of spring wheat. In addition to the milling and baking data are given the average grade, the average bushel weight, and the average yield of the varieties for the four years 1918 to 1921, inclusive. The figures given for the milling and baking data are also averages for the same four years.

This table shows that Kharkov was the best milling wheat of the five winter varieties. The loaf volume of Kharkov, however, was exceeded by that of Hybrid 123. The latter variety was slightly lower in bushel weight and yielded 3 percent less flour. The texture and color of the loaves made from Hybrid 123 averaged somewhat lower than the loaves made from Kharkov. The average data for the Triplet variety also compare very favorably with those of Kharkov. Its average weight per bushel was as high, its loaf volume was nearly as high, and the texture and color of the loaves were equally as good as those made from Kharkov. Triplet was 5 percent lower in yield of flour than Kharkov. Hybrid 128 did not make a very good showing as compared with the three varieties named above, and Fortyfold was the poorest milling wheat of the five. On the market, Hybrid 123 usually brings a lower price than Hybrid 128. The average milling and baking data for four years show that Hybrid 123 when grown as a dry-land wheat, is of considerably better milling quality than Hybrid 128. For the four-year period, however, the yield of Hybrid 128 averaged 1.4 bushels an acre more than Hybrid 123. Fig. 12 shows cross-section of loaves of winter wheats.

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*For further description of the Federation wheats, see Bulletin No. 877, United States Department of Agriculture, Australian Wheat Varieties in the Pacific Coast Area.

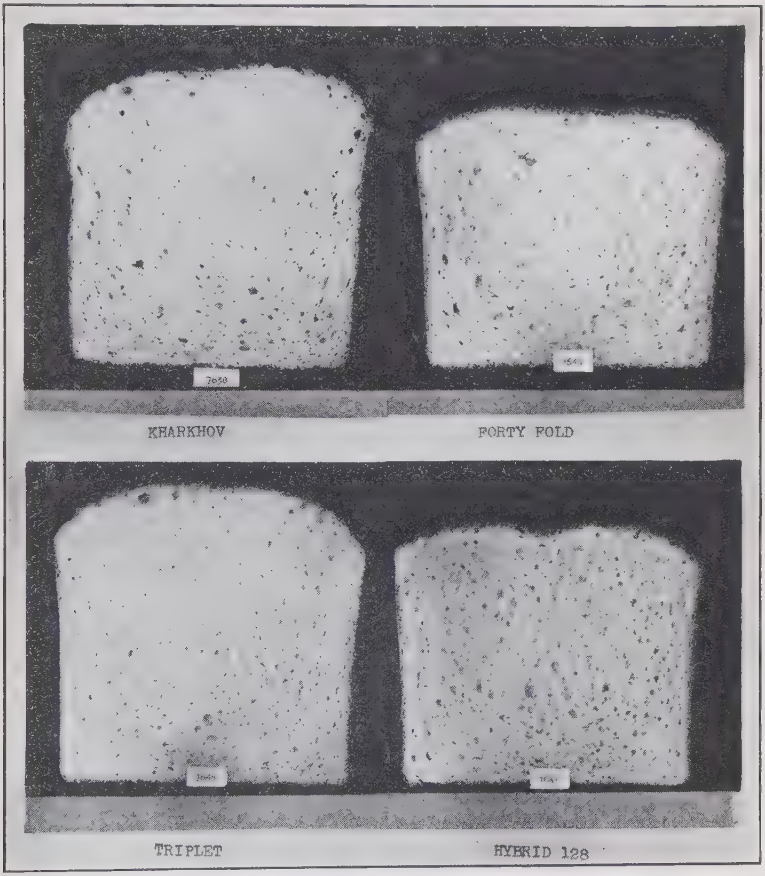

Fig. 12. Cross-section of loaves of bread made from four winter-wheat varieties of the crop of 1921

The average data for the spring-wheat varieties show that in loaf volume Marquis slightly exceeded the others, though it was only 7 c. c. higher than Bobs. Bobs exceeded Marquis by 4 percent in flour yield and averaged higher than any other spring-wheat variety. The loaf volume of Hard Federation for the four years averaged slightly lower than Marquis but was higher in flour yield and 5.6 lbs. higher in test weght. The Hard Federation also exceeded Early Baart in loaf volume and in flour yield. The texture and color of the loaves made from Hard Federation were slightly better than those from Marquis and also better than those from Early Baart. Cross-sections of typical loaves are shown in Fig. 13. For the four years, the average loaf volume of the five spring wheat varieties exceeded the average loaf volume of the winter wheat varieties about 20 percent. As is shown in Table XIII, the spring wheats from every standpoint were better milling varieties than the winter wheats. The spring wheats averaged less in bushel weight and 10.4 bushels less in acre yield than the winter wheats.

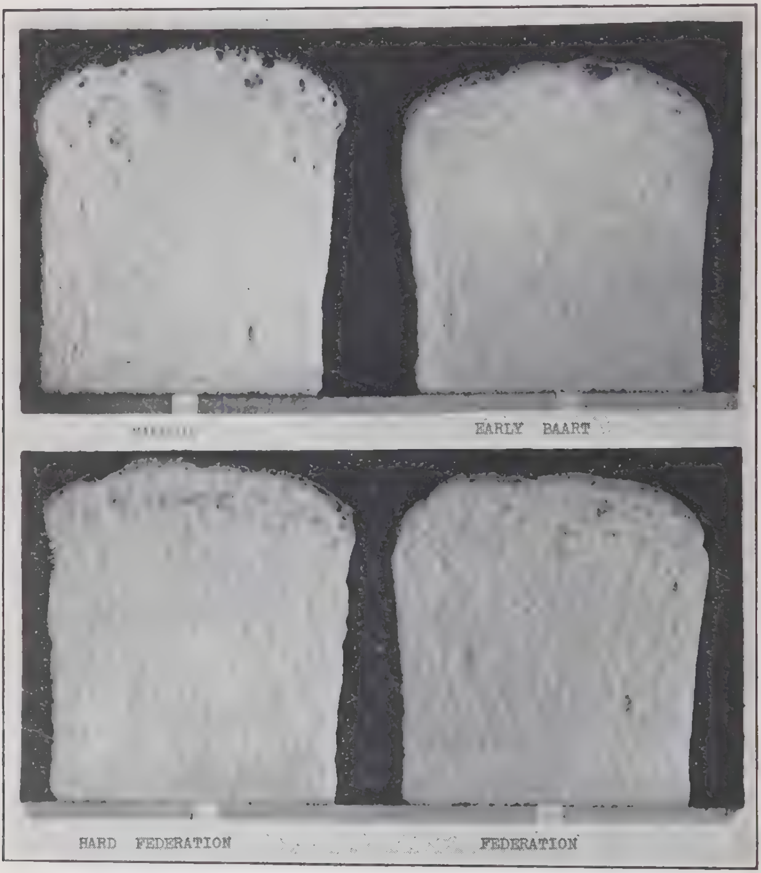

Fig. 13. Cross-section of loaves of bread made from four spring-wheat varieties of the crop of 1921.

TABLE XIII. AVERAGE YIELD AND AVERAGE MILLING AND BAKING DATA FOR WHEAT VARIETIES GROWN AT MORO, OREGON, UNDER SIMILAR CONDITIONS FOR THE YEARS 1918 TO 1921, INCLUSIVE

Variety	C. I. No.	Yield 1918-21	Bushel weight	Grade	Protein	Flour	Loaf volume	Texture	Color
		bu.	lbs.		%	%	c. c.	%	%
Winter Wheats—									
Kharkov	1442	34.9	60.4	1 Dark Hard Winter	10.6	70.9	1897	89.1	90.4
Triplet	5408	34.5	60.4	1 Red Winter	11.3	65.9	1867	89.4	90.6
Hybrid 123	4325	35.3	59.8	1 Red Walla	11.7	67.9	1900	88.7	88.4
Hybrid 128	4326	36.7	58.0	2 White Club	12.6	68.2	1795	86.2	87.5
Fortyfold	4156	26.5	57.6	3 Soft White	12.8	70.1	1602	83.1	86.5
Average		33.6	59.3		11.8	68.6	1812	87.3	88.7
Spring Wheats—									
Marquis	4158	19.1	53.5	5 Dark Northern Spring	15.7	69.8	2302	91.2	89.0
Early Baart	1697	21.2	58.3	2 Hard White	13.1	68.1	2080	89.7	91.1
Hard Federation	4733	26.2	58.1	2 Hard White	13.9	71.4	2105	91.7	92.4
Federation	4734	26.0	55.6	4 Hard White	13.4	69.7	2082	88.9	87.2
Bobs	2826	22.7	56.9	3 Hard White	14.0	72.8	2295	91.5	91.9
Average		23.0	56.5		14.0	70.3	2173	90.6	90.3

Station Bulletin 191 July, 1922

Oregon Agricultural College

Experiment Station

Growing Irrigated Crops in Harney Valley

By

OBIL SHATTUCK and DOUGLAS W. RITCHIE

CORVALLIS, OREGON

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SUMMARY

Harney Valley has a vast area of irrigable land that will eventually be irrigated by gravity or pumping.

The irrigation investigations at the Station cover the important factors relating to successful irrigation practice.

The soil type on which the Burns Station is located, is average to poor, as compared with the Valley proper.

The climate of Harney Valley is arid. The precipitation is very light, the evaporation high, and frosts are frequent.

Land should be carefully leveled for irrigation.

The border system of irrigation is one of the best, and is rapidly coming into general use in irrigated sections.

The check system is not recommended for Harney Valley conditions.

The corrugation system is well suited to land sloping in different planes.

The furrow system is well adapted to the irrigation of row crops.

Sub irrigation can be used to advantage on grain and alfalfa where soil conditions permit.

Flooding is a wasteful method of irrigation.

Cleaning and grading all classes of seed, nets the irrigation farmer large returns.

Treating all cereals for smut is essential for good yields.

Federation is the best spring wheat to grow under irrigation.

Turkey Red is the best winter variety, but care must be taken not to over-irrigate this crop, or lodging will result.

Hannchen and Trebi barleys are excellent yielders under irrigation.

Rustless Selection, Swedish Select, and Silvermine are the best oat varieties.

Rye is a dry-land crop and not as good a yielder under irrigation as wheat, barley, or oats.

Grimm alfalfa is the best forage crop for Harney Valley.

Kaiser field peas, when grown for seed, or in combination with oats or wheat, produces excellent yields of hay or silage. It is one of the best legumes to grow in a short rotation.

The clovers are not well adapted to conditions in Harney Valley.

Mammoth Russian sunflowers produce the largest tonnage of silage.

Peas and oats are the best combination crop for Harney Valley.

Early-maturing varieties of potatoes do well in warmer sections.

Sugar beets and mangels do well in some sections but are not as sure as cereal or forage crops.

Field peas in the short rotation and alfalfa in the long rotation have given best returns.

The irrigator must learn from practical experience when the crop needs water. No hard and fast rules can be laid down. Frequent light irrigations are better than heavy ones at long intervals.

Too much water will reduce the yields and injure the soil.

Under the heading "Cost of irrigation by Pumping," the figures represent the pioneer stage. Transportation, cheaper fuel, or adequate power lines would materially reduce the cost per acre.

Growing Irrigated Crops in Harney Valley

By

OBIL SHATTUCK, Superintendent

and

DOUGLAS W. RITCHIE, Assistant in Irrigation

INTRODUCTION

Irrigation is destined to play an important part in the agriculture of Harney Valley. There are approximately thirty thousand acres of irrigable land in the Valley proper. Irrigation investigations have been added to the work of the Burns Station as one of its important projects.

The work of the Station from the time of its establishment in 1911 until the spring of 1916 was confined to dry farming by the summer-fallow method. In 1917 a deep well was drilled and a pumping plant installed to provide water for the irrigation investigations. The work has been carried out with the advice and cooperation of the main Station at Corvallis. This publication reports briefly the progress to date and offers suggestions based upon the results obtained.

Object of the Investigations

The object of these investigations is—

1. To determine whether the cereal, forage, root, and miscellaneous crops can be successfully and profitably produced.

2. To determine by actual application, the amount of water required by each crop for highest economical returns.

3. To determine the best crop rotation for yield, economy, and fertility.

4. To determine the plant food needs of these soils for crop production.

5. To determine the best time, rate, and date of seeding irrigated crops.

6. To secure data on the possibilities of irrigation by pumping.

LOCATION AND SOIL TYPES

The Burns Station is located six miles east of Burns, Oregon, on typical sage-brush land varying from sandy loam to sandy silt or clay loam, the major portion of which is spotted with alkali. The soil is considered average to poor, as compared with the valley proper. Geologically classified, the soils of Harney Valley are lake and stream deposits from sedimentary rocks.

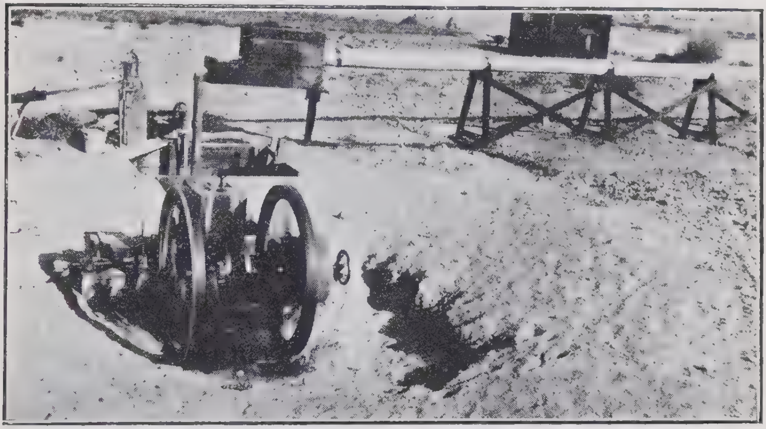

Fig. 1. The pumping plant in operation at the Burns Station.

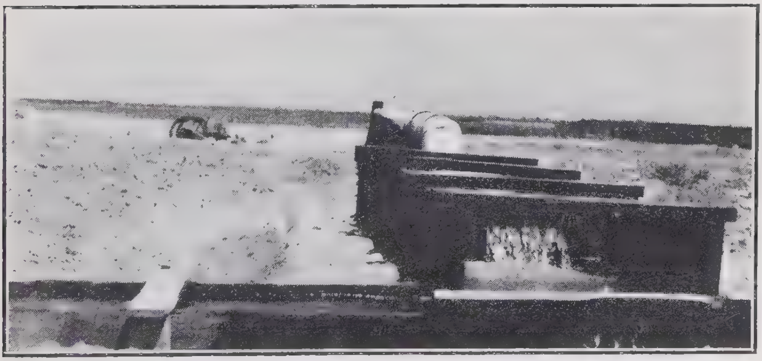

Fig. 2. Weir box on Burns Station.

CLIMATE

The general climate of Harney Valley is dry. The average elevation is about 4,100 feet. The extreme temperatures range from 100° Fahrenheit in summer to minus 30° in winter. Summer frosts are frequent.

The annual average precipitation from 1914 to 1921 was 9.02 inches. Most of the precipitation comes in the winter and early spring. The average annual evaporation from a free water surface for the past eight years, April to October inclusive, was 42.6 inches. The average wind velocity from 1914 to 1921 was 4.1 miles per hour.

PREPARATION OF LAND FOR IRRIGATION

Make a Contour Map. First, a contour map of the field to be irrigated should be made, noting the high and low places, general slopes and natural drainage. Second, the system of irrigation should then be decided upon, whether contour flooding, border, check irrigation, or sub irrigation. This will depend on the contour of the field, type of soil. and head of water.

Clearing and plowing on the Station in 1912 cost approximately $5.00 an acre.

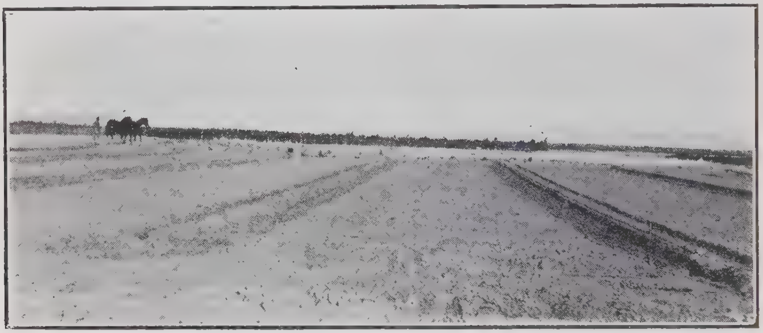

Fig. 3. The finished field, ready for seeding.

Leveling. To succeed with irrigation it is important that the land be properly leveled. Land well leveled at the start affords larger returns, requires less water and less labor for proper irrigation. A small farm level is very useful in preparing the land for irrigation. With this instrument all guess work is eliminated and the increased yields from well leveled fields will more than pay for the instrument on the first crop harvested.

How to Level. The best method of land leveling is to plow or double disk all of the high spots; and then fill all of the low places by scraping in this soil with a Fresno, buck-scraper, or some form of wheel scraper. This permits the moving of the soil over solid ground, making the work lighter on both man and team. About an acre a day may be leveled with a four-horse Fresno under rather level conditions.

Irrigate to Settle Soil. The fields should then be double disked or spring toothed and floated. This fills minor depressions. A trial irrigation should then be made to settle the ground and prove the leveling. When the field is again dry enough to work it should be plowed six to eight inches deep and immediately double disked or spring toothed.

During the winter this should settle into a good seed bed. As soon as possible in the spring, the land should be double disked and harrowed, or spring toothed, floated, and laid out according to the irrigation system to be used. If, in making dikes or borders, the soil is removed to any extent, it is a good plan to refloat the edges. Leveling land in the fall is best, but good results have been secured with spring leveling. An orchard or reversible disk harrow, with disks reversed to throw the dirt in, is useful in making borders.

SYSTEM OF IRRIGATION TO USE

The system to select will depend upon the contour of the field, irrigation head, type of soil, and kind of crop. The general or wild flooding system is not to be recommended; it wastes water, injures the soil, gives low returns, and in the end proves to be very expensive.

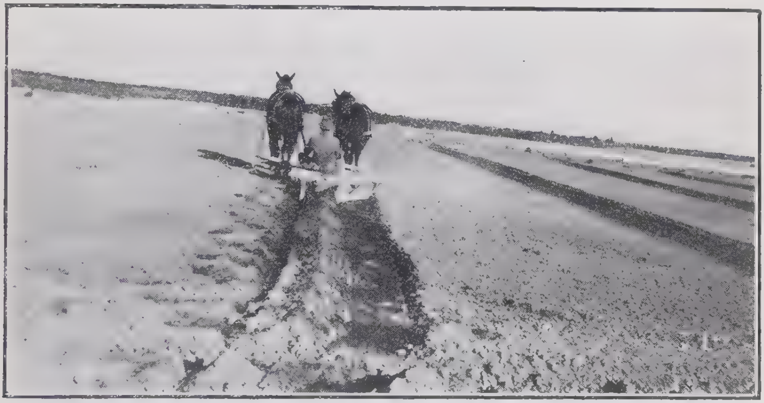

Fig. 4. Making the borders. A round trip completes the border or dike.

The Border System. The border system in many irrigated sections is becoming quite popular. If the land is fairly level or gently sloping, it proves very efficient. The borders or dikes can run down the slope and may be from thirty to fifty feet apart, depending upon the soil type and head of water to be used. These are made ten inches high by three to five feet wide, by plowing a dike furrow and following with a ridger as shown in Fig. 4. Care should be taken to remove the side slope when leveling. A table should be provided by grading to a level plane a strip ten to fifteen feet wide at the head of the strip. This facilitates the distribution of water. The length of borders will depend upon the type of soil, short runs being used on sandy soil and running up to four hundred feet on the heavier types. A good head of water is needed, ranging from one-half cubic foot per second up to two or three second feet.*

The Check System. This method can be used only on rather flat land. It is an efficient system but requires more leveling than the border system, and is not so satisfactory for local conditions.

The Corrugation System. This consists of making a series of small parallel furrows, eighteen to thirty-six inches apart, after the crop is seeded. It is a good system for rather uneven ground where the field slopes several ways. Where the slope is pronounced, the corrugation should follow the contour of the land in order to prevent washing.

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*Oregon Agri. Col. Exp. Sta. Bulletin 177. The Management of Sandy Soils Under Irrigation, by H. K. Dean.

The Furrow System. This system is adapted to the irrigation of row crops where the land has a fairly uniform slope. It enables the irrigator to supply the water to the lower part of the rooting system of the plant without causing the soil surface to become hard and compact.

Sub Irrigation. This method is very efficient where the soil formation permits a rapid horizontal movement of water without great loss by downward percolation. It is practiced in portions of the Harney Valley on alfalfa and grain. The water is held in fairly wide ditches at a rather high level and sub irrigates the soil. These main ditches vary in distance apart from fifty to three hundred yards.

FIRST CROPS FOR NEW LAND

Use Annuals. The first and second crops should be annual, preferably cereal, annual legumes or row crops, as sunflowers or roots. It is poor practice to seed newly prepared and unsettled land to a permanent crop, as alfalfa or other meadow crops. Low spots that have been filled in will settle; these low places will get too much water and often the crop kills out, which results in thin stands and low yields. By growing annual crops for one or two years, an opportunity is given for re-leveling before the permanent alfalfa crop is established.

Fig. 5. Irrigated spring wheat varieties, 1920, 13 varieties averaged 61.2 bushels per acre. The federation made 82.4 bushels per acre.

THE PRODUCTION OF IRRIGATED CROPS

CEREALS

Wheat, barley, oats, and rye yield well in the Harney Valley and as irrigated grain crops rank in importance in the order named. Only high yields of grain can pay on irrigated land. High yields can be secured most easily by the following method:

1. Grow nothing but the highest yielding variety.

2. Carefully clean and grade the seed through a good fanning mill to eliminate all weed seeds and all small, light, broken and damaged seed.

3. Treat wheat, oats, and barley to avoid losses by smut.

4. Plant early and shallow to medium in depth as these methods secure the best stand.

5. Grow cereals in rotation with legumes, as the Harney Valley soils are naturally somewhat deficient in nitrogen and this element is supplied by the legume crop in the rotation.

STANDARD VARIETIES

The experiments of five seasons show Turkey Red to be the best variety of winter wheat; Federation the best variety of spring wheat; Trebi or Hannchen the best of the spring barleys, and Swedish Select and Silvermine the best spring oats. To grow other varieties than these in the high irrigated districts results automatically in a loss.

PREPARATION OF SEED FOR PLANTING

Cleaning and Grading Seed. Sowing seed just as it comes from the threshing machine is an expensive and wasteful practice, since it results in lower yields, and a waste of material that might otherwise be used for feeding purposes. All seed should be put through a fanning mill and grain grader to blow out the light seed, and sort out weed seeds, broken and undersized kernels, which may in many cases be used for feed. By cleaning and grading the seed, better stands of stronger and more vigorous plants may be secured. Table I shows individual and average differences of yields from cleaned grain as compared with grain direct from the threshing machine. There was an average gain of 5.6 bushels an acre from carefully cleaned seed over that of seed directly from the thresher.

TABLE I. YIELDS OF SPRING WHEAT FROM THRESHER RUN AND FROM CAREFULLY CLEANED AND GRADED SEED ON IRRIGATED LAND AT THE BURNS STATION, 1921

Cereal Inv. No.	Variety	Yield in bushels per acre		
		Thresher run	Cleaned and graded seed	Increase
		bu.	bu.	bu.
2826-1	White Bobs	42.0	45.8	3.8
6255	Red Bobs	45.1	45.8	0.7
4158	Marquis	44.0	51.8	7.8
5284	Acme Durum	40.6	47.6	7.0
1697	Early Baart	49.1	58.1	9.0
Average		44.2	49.8	5.6

Treatment for Smut. All wheat, oats, and barley should be treated for smut previous to seeding. This treatment is applied after the seed has been cleaned and graded. The formaldehyde treatment is probably best for the irrigated cereals. One pint of formaldehyde is mixed in forty-five gallons of water. With carefully recleaned grain, this solution may be sprinkled on the seed at the rate of about one-half gallon per bushel. The dampened grain should be thoroughly shoveled over two or three times to get it all uniformly wet. It is then covered with wet sacks or canvas and left covered for a period of two to three hours. It should then be shoveled out so that the remaining formaldehyde may escape. Seeding should take place as soon as it will run through the drill.

Where seed has not been properly cleaned, it should be treated in the formaldehyde solution for three to five minutes, then drained of the solution and planted within twenty-four hours in soil sufficiently moist for prompt growth. Oats are usually dipped in sacks, while it is best to treat the wheat or barley loose in vats so that smut balls may be skimmed off. When treating grain loose, it should be thoroughly stirred and skimmed to remove floating smut balls and other light material.

SPRING WHEAT

Federation is Best. Seventeen varieties of spring wheat have been grown on the Burns Station under irrigation. Federation, C. I. 4734, is the best variety. It was introduced into the United States from Australia by the United States Department of Agriculture. It was first grown by Superintendent D. E. Stephens at the Branch Experiment Station at Moro, Oregon, and seed for the Burns Station was secured from this place. It is now being extensively grown in Southern Idaho, where under irrigation it is superseding Dicklow.

Federation is a beardless, brown-chaffed wheat that grades from soft to hard white, depending upon the conditions under which it is grown. It has a stiff straw. Among the seventeen spring wheat varieties, it stood up 100 percent while the remaining varieties lodged 10 percent to 100 percent. It is an excellent yielder, matures moderately early, does not shatter badly, and is rather a good milling wheat.

TABLE II. ANNUAL AND AVERAGE YIELDS OF SPRING WHEAT ON IRRIGATED LAND AT THE BURNS STATION FOR 1920 AND 1921

C. I. No.	Variety	Yield, bushels per acre		
		1920	1921	Average
		bu.	bu.	bu.
1697	Early Baart	65.0	36.4	50.7
3663	Dicklow	77.1	45.4	61.2
4067	Pacific Bluestem	57.5	42.7	50.1
4158	Marquis	64.0	36.0	50.0
4066	Little Club	......	38.0	38.0
4734	Federation	82.4	50.9	66.6
6227	Golden Ball (Durum)	55.3	43.4	49.3
2826-1	White Bobs	64.0	33.7	48.8
5284	Acme Durum	50.9	42.0	46.4
6255	Red Bobs (from Canada)	60.0	31.1	45.5
4733	Hard Federation	55.1	28.5	41.8
4981	White Federation	......	23.3	23.3

WINTER WHEAT

Turkey Red the Standard Variety. Winter wheat will do very well under irrigation in some sections of Harney Valley. It is doubtful if it will prove as satisfactory as the best spring varieties. Turkey Red is the leading winter variety, but has rather weak straw and is apt to lodge, unless the water is carefully applied. It should not be heavily irrigated. Irrigation should stop rather early so the crop may mature.

TABLE III. ANNUAL AND AVERAGE YIELDS OF WINTER WHEATS GROWN ON IRRIGATED LAND AT THE BURNS STATION FOR THE YEARS 1919 TO 1921 INCLUSIVE

		Yield in bushels per acre				
C. I. No.	Variety	1919	1920	1921	Ave.	Percent of Kharkov
		bu.	bu.	bu.	bu.	%
1558	Turkey Red	18.6	38.0	70.0	42.2	104
1442	Kharkov	21.3	34.9	64.7	40.3	100
5146	Kanred	20.0	30.8	64.4	38.4	95
4512	Washington Hybrid 128	22.6	34.3	58.1	38.3	95
4066	Little Club	21.3	38.6	48.3	36.0	89

BARLEY

Barley Good Hog Feed. Barley is a good yielder in Harney Valley and should be grown more extensively for feed. Ground or rolled barley is an excellent feed for horses and will produce a better grade of pork than corn. The meat will be firmer and not so fat.

Of the twelve varieties grown under irrigation at the Station, two are very good. These are Hannchen, a white, bearded, two-row barley and Trebi, a blue, bearded, six-row barley. Both yielded at the rate of 105 bushels an acre in a rate of seeding test. Both varieties mature moderately early and have rather stiff medium length straw.

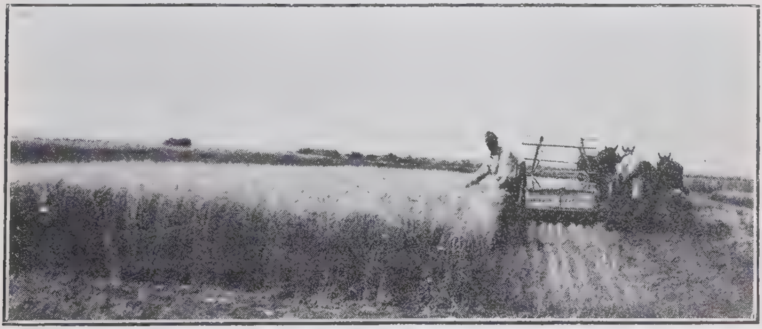

Fig. 6. Hannchen barley yields well under irrigation.

OATS

Oats do well in Harney Valley and are excellent for feeding horses. The crop is hardy and yields well under irrigation.

Of the nine varieties grown at the Station, the Rustless Selection, Swedish Select and Silvermine are best, although the Rustless Selection has rather a light kernel.

TABLE IV. ANNUAL AND AVERAGE YIELDS OF SPRING OATS UNDER IRRIGATION AT THE BURNS STATION FOR THE YEARS 1919 TO 1921 INCLUSIVE

C. I. No.	Variety	Yield, bushels per acre 1919	1920	1921	Ave.	Percent of Swedish Select
		bu.	bu.	bu.	bu.	%
724	Rustless Selection	45.0	127.3	70.8	81.0	111.0
134	Swedish Select	38.0	117.1	63.5	72.8	100.0
625	Sixty Day	35.5	91.7	52.4	59.9	80.9
720	Silvermine	35.8	106.8	61.8	68.1	93.5
658	Big Four	33.0	94.5	70.8	66.1	90.7
841	Nebraska 21	......	96.4	55.5	75.6	103.0
......	Hulless	......	81.3	62.0	71.6	98.2
708	Fulghum	......	87.9	48.2	68.0	93.4

Fig. 7. Irrigated oat varieties, 1920. Five varieties exceeded 100 bushels per acre.

RYE

While rye yields fairly well under irrigation, it cannot be considered a paying crop except where it is produced for seed. There is quite a demand for the true spring rye, which is rapidly replacing the winter varieties.

TABLE V. ANNUAL AND AVERAGE YIELD OF IRRIGATED SPRING RYE AT THE BURNS STATION

Variety	Yield, bushels per acre 1917	1918	1919	1920	Average
	bu.	bu.	bu.	bu.	bu.
Vern. S. P. I. No. 26101	12.9	13.0	18.2	38.9	20.7

FORAGE CROPS

Forage Production Vital. As Harney Valley is essentially a range stock country, forage crops for winter feed are of prime importance. Excellent yields of Grimm alfalfa, field peas, and sunflowers have been produced in the Valley, under irrigation. The old type of farming—that of raising one-half to three-fourths of a ton of wild meadow hay to the acre, with approximately three acre feet of water—is being replaced by alfalfa and grain fields with the water controlled. This results in increased production and better feed with half of the amount of water formerly used.* (See Table 15.)

ALFALFA

Sow Seed Shallow. The seed bed for alfalfa must be fine and firm. It is best to sow shallow with a drill, as it insures uniform distribution of the seed. Care must be taken to prevent deep seeding. One inch is deep enough for alfalfa. The pressure springs should be released from the furrow openers of the drills so they will not run too deep.

Good stands can be secured by broadcasting and harrowing, but this method requires from 30 to 50 percent more seed and the stand is apt to be uneven.

Grimm is the Best Variety. Grimm alfalfa has proved to be the hardiest, highest yielding variety, both for hay and seed in Harney Valley.

TABLE VI. ANNUAL AND AVERAGE YIELDS OF ALFALFA UNDER IRRIGATION AT THE BURNS STATION FOR THE YEARS 1918 TO 1920 INCLUSIVE

Variety	Yield, tons per acre, cured hay 1918	1919	1920	Average
	tons	tons	tons	tons
Grimm (Baltic)	2.7	4.4	4.9	4.0
Grimm	1.7	4.3	4.7	3.6
Turkestan	1.7	3.9	4.8	3.5
Common	1.7	3.7	4.4	3.3

TABLE VII. ANNUAL AND AVERAGE YIELD OF ALFALFA SEEDED IN 1920 AND GROWN AT THE BURNS STATION UNDER IRRIGATION IN 1920 AND 1921

Variety	Yield, tons per acre, cured hay 1920	1921	Average
	tons	tons	tons
Grimm	.7	7.0	3.9
Dakota Diamond	1.1	6.4	3.7
Martin's Acclimated	.9	6.3	3.6
Cossack	.8	6.2	3.5
Turkestan	.6	5.8	3.2
Liscolm	1.0	5.3	3.1
Smooth Peruvian	1.2	4.8	2.9
Hairy Peruvian	1.3	3.3	2.3

FIELD PEAS

Good for Silage. Field peas are valuable in Harney Valley for silage, for hay, and as a grain crop, when grown alone, or in combination with wheat or oats, and for their fertilizing effect when grown in the short rotation. Field peas produce excellent pork when fed in combination with wheat or barley.

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*The Improvement and Irrigation Requirement of Wild Meadow and Tule Land, Oregon Agri. Col. Exp. Sta. Bulletin No. 167, by W. L. Powers and W. W. Johnston.

TABLE VIII. ANNUAL AND AVERAGE YIELDS OF FIELD PEAS FOR HAY AND GRAIN, GROWN UNDER IRRIGATION AT THE BURNS STATION

	Yield, tons of hay* and bushels grain per acre							
	1919		1920		1921		Average	
Variety	tons	bu.	tons	bu.	tons	bu.	tons	bu.
Kaiser	2.5	36.5	4.1	0.0	4.5	48.6	3.7	42.5

*All peas were cut for hay in 1920.

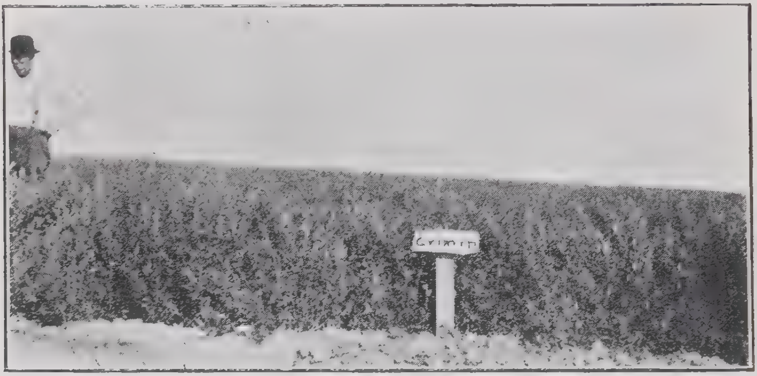

Fig. 8. Grimm alfalfa, the best forage crop for Harney Valley. Yielded 7.0 tons per acre 1921.

Fig. 9. Field peas for grain, yield 48.6 bushels.

CLOVERS

Clovers Not as Good as Alfalfa. Red clover and white sweet clover have not done very well at the Station. White sweet clover makes a wonderful growth in some sections of the Valley. This crop is very good for green manure in reclaiming some of the poorer soils and also makes good silage when grown alone or in combination with oats.

It is difficult to secure a uniform stand of sweet clover in some sections. The seed has a hard or waterproof seed coat and should be scarified before sowing. The seed bed should be finely worked and firm. The seed may be drilled shallow or it may be broadcasted, but the former method is preferable.

TABLE IX. ANNUAL AND AVERAGE YIELDS OF RED CLOVER AND WHITE SWEET CLOVER, UNDER IRRIGATION, AT THE BURNS STATION

Kind	Yield, tons per acre cured hay 1920	1921	Average
	tons	tons	tons
Red clover	2.2	3.4	2.8
White sweet clover	2.2	4.3	3.2

SILAGE CROPS

SUNFLOWERS

Sunflowers Yield Well. Sunflowers, as a silage crop, have proved to be a leader in Harney Valley during the past two years. Splendid yields were secured in 1920 and 1921. The best way to handle sunflowers as indicated by the available data, is to seed them in rows 21 inches apart, with a regular grain drill, at the rate of 25 to 35 pounds an acre. Two rows at a time can be harvested with an ordinary mower. A sharp sickle and plenty of speed are essential. The crop should be cut close to the ground.

When to Harvest. They may be harvested any time from full bloom until the seeds are in the stiff dough. About 13 tons of whole, green, sunflowers were fed to Station stock, horses and cows, and were readily consumed. The stock left choice alfalfa hay to eat sunflowers.

TABLE X. ANNUAL AND AVERAGE YIELD OF MAMMOTH RUSSIAN SUNFLOWERS GROWN UNDER IRRIGATION WITHOUT CULTIVATION, AT THE BURNS STATION FOR THE YEARS 1920 AND 1921

Variety	Rate of seeding	Distance apart of rows	Acre inches irrigation	Year	Yield per acre
	lb.	in.	in.		ton
Mammoth Russian	5	36	19.5	1920	27.6
Mammoth Russian	30	21	19.5	1920	54.7
Mammoth Russian	15	14	19.5	1920	43.6
Mammoth Russian	30	7	19.5	1920	42.8
Mammoth Russian	35	21	15.0	1921	31.0
Mammoth Russian	35	21	20.0	1921	38.3
Mammoth Russian	35	21	25.0	1921	38.1
Mammoth Russian	35	21	24.0	1921	54.1
Mammoth Russian	35	21	27.0	1921	51.5

Note: Yields are reported as green weight in tons per acre at the silage stage.

The highest yield was secured when the sunflowers were sowed thickly in twenty-one inch rows and were heavily irrigated. It is important that sunflowers be planted and irrigated so they will head out and reach a good stage of maturity. Probably water should be kept off late in the season. Early varieties should be grown.

Some work with sunflowers has indicated that when green or dry plants such as corn or oats can be cut into the silo with sunflowers, better silage is secured.

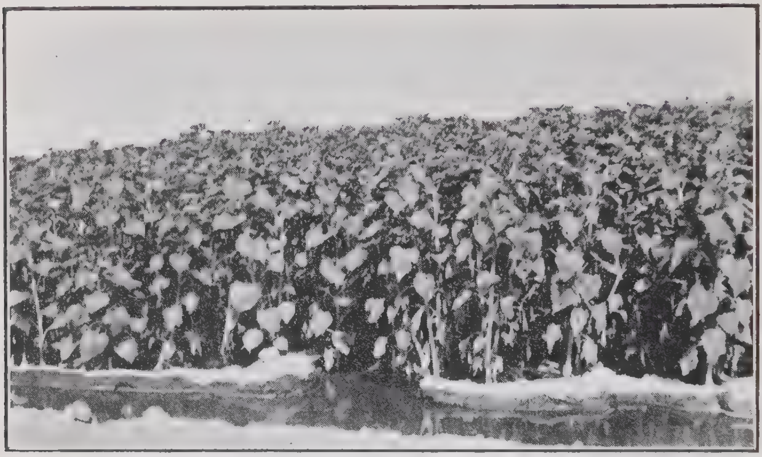

Fig. 10. Irrigating sunflowers. Yield 54.7 tons per acre green weight.

OTHER SILAGE COMBINATIONS

A combination of field peas and wheat seeded at the rate of 1 and 2 bushels respectively, yielded at the rate of 14.1 tons per acre for silage, and 6.2 tons when cured for hay.

A combination of field peas and Silvermine oats seeded at the rate of 1 and 2 bushels respectively, yielded at the rate of 14.8 tons of silage and 6 tons of cured hay per acre.

Fig. 11. Peas and oats for hay or silage. Yield for hay 6.2 tons, for silage 14.8 tons

POTATOES

Potatoes Best on Slopes. Potatoes make excellent yields in some of the more sheltered sections of the Valley, especially along the foot hills. On the Valley floor proper the crop is sometimes killed by frost. However, some very good yields have been secured.

In most sections, this crop should not be planted until the latter part of May. In some sections potatoes may be planted early in April.

TABLE XI. ANNUAL YIELDS OF POTATOES UNDER IRRIGATION AT THE BURNS STATION

Variety	Yield, bushels per acre 1919	1921
	tons	tons
Early Six Weeks (Geer)	79.2	......
Early Ohio	83.3	176.0
Bliss Red Triumph	73.3	...
Irish Cobbler	81.6	...
Extra Early Rose	124.2	......
White Pinkeye (Local)	75.0	195.0
Eureka	85.8	......
Netted Gem	91.6	161.0
Red Pinkeye (Local)	..	220.0

ROOT CROPS

Root crops are not as sure in the Harney Valley as cereal or forage crops, but good yields have been secured.

SUGAR BEETS AND HALF SUGAR MANGELS

Sugar beets and mangels, like potatoes, are rather uncertain crops for the Valley proper, but can be grown to advantage in the warmer sections. Mangels make excellent feed for all kinds of stock, and several tons have been fed to Station stock with good results. Sugar beets and mangels require a finely worked, firm seed bed. They should be seeded in rows 30 to 36 inches apart, and thinned to single plants, ten inches apart in the row, when the fourth leaf appears. They should be well cultivated.

TABLE XII. AVERAGE YIELDS IN TONS AN ACRE OF HALF SUGAR MANGELS AND SUGAR BEETS GROWN UNDER IRRIGATION AT THE BURNS STATION

Half sugar mangels 1919	Sugar beets 1921
6.2	6.1

RUTABAGAS

Rutabagas are hardy and make good yields. The half sugar mangel is more readily eaten by stock.

RATE AND DATE OF SEEDING

Table XIII gives the best rates of seeding for the various crops according to the present data. The dates of seeding will vary more or less, according to locality, but are reasonably correct for the Valley proper.

TABLE XIII. RECOMMENDED RATES AND DATES OF SEEDING IRRIGATED CROPS AS WORKED OUT AT THE BURNS STATION FOR HARNEY VALLEY

Crop	Rate of seeding	Date of seeding
Spring wheat	2 bushels	April 1 to 25
Winter wheat	2 bushels	Sept. 1 to 15
Spring barley	2½ to 3 bushels	April 20 to May 10
Spring oats	2½ to 3½ bushels	April 1 to 25
Spring rye	2 to 2½ bushels	April 1 to 25
Grimm alfalfa	10 to 20 pounds	April 25 to June 1
Clover	10 to 15 pounds	April 25 to June 1
Field peas	1 to 2 bushels	April 1 to 25
Sunflowers	20 to 25 pounds	May 1 to 25
Peas and grain combination	2 to 3 bushels	April 1 to 25
Potatoes	1½ to 2 ounce piece per hill	May 15 to 25
Sugar beets	8 to 12 pounds	May 15 to 25
Mangels	8 to 12 pounds	May 15 to 25
Rutabagas	3 to 5 pounds	April 15 to 25

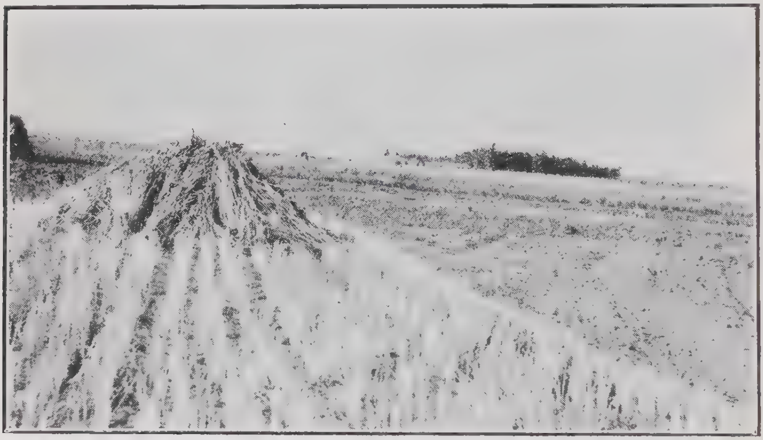

Fig. 12. Irrigated rotations. Grain continuous, yield 23.3 bushels per acre.

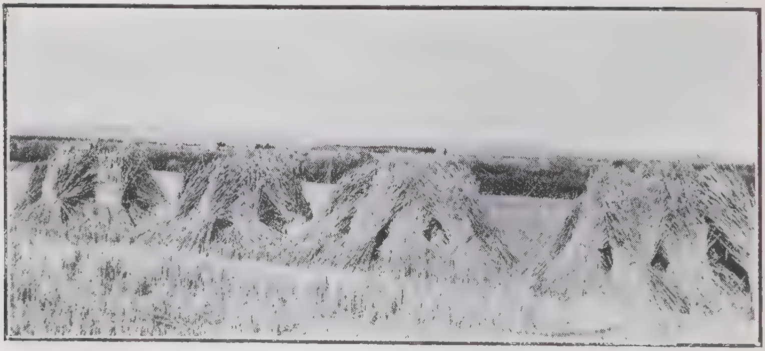

Fig. 13. Irrigated rotations. Grain on field pea stubble, yield 61.1 bushels per acre.

IRRIGATED ROTATIONS

Several rotations are being tried at the Station. The two giving the best results to date are the two- and six-year rotations.

The two-year rotation, grain following field peas, has given excellent results. The yield of Federation spring wheat seeded on field pea stubble was 61.1 bushels per acre, while the yield of the same variety of wheat grown on a plot of land that had been cropped to grain continuously since 1917 was 23.3 bushels per acre. This represents a gain of 37.8 bushels per acre in favor of the rotation. Effect of rotation upon yield of grain is shown in Table XIV. As the depth of irrigation is about 12 inches a year, rotation has caused the increase in yield of two bushels per acre inch.

TABLE XIV. AVERAGES IN SUMMARY—GRAIN IN IRRIGATED ROTATION. BURNS STATION

Rotation No.	Crop sequence	Barley 1917	Barley 1918	Barley 1919	Barley 1920	Wheat 1921	Average of barley (all yrs.)
		bu.	bu.	bu.	bu.	bu.	bu.
1	Grain Continuous	21.26	30.76	29.2	46.26	32.6	31.87
	Grain after field peas[4]	[5]18.8	59.85	36.76	81.8	47.9	59.47
[4]2 and 5	Gain over continuous	....	29.09	7.56	35.54	15.3	34.26
4	Grain after roots	[5]14.9	[1]58.0	27.4	83.5	45.5	55.4
	Gain over continuous	....	[1]27.24	–1.8	37.2	12.9	17.7
3	Grain after green manure[2]	[5]14.0	56.3	34.0	....	33.8	45.1
	Gain over continuous	....	25.5	4.8	....	1.2	15.1
6	Grain — rye hay — pea hay	[5]7.3	35.6	27.76	....	....	31.68
	Gain over continuous	....	4.9	–1.4	....	....	1.75
7	Alfalfa 4 yrs. Grain 2 yrs.	[5]21.2	....	....	....	39.1	....
	Gain over continuous	....	....	....	....	6.5	....
	Average all rotated grain	....	50.58	31.38	82.6	41.5	54.85
	Average increase all rotation	....	19.83	2.18	46.34	8.9	22.78

[1] After fallow 1918 not included in average.
[2] Pea hay.
[3] Grain and alfalfa (alfalfa not completely eradicated).
[4] Field peas substituted for sweet clover in rotation 5.
[5] Grain first in rotation. Not included in average.

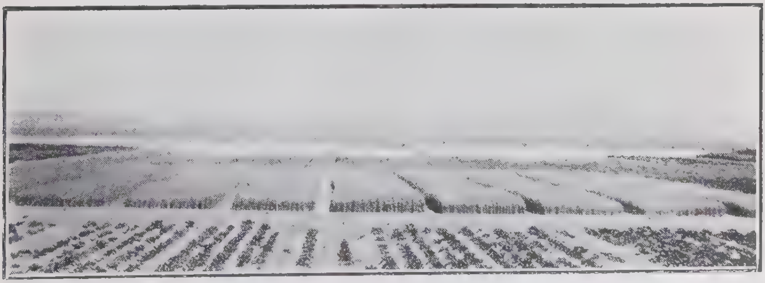

Fig. 14. Fertilizer experiment with Federation wheat. The first four plots from right to left yielded at the rate of 79.5, 80.0, 80.7, and 80.0 bushels per acre.

Crop rotations that include leguminous crops, not only maintain the nitrogen of the soil but may build it up, thus increasing the producing power and returns per unit of water.

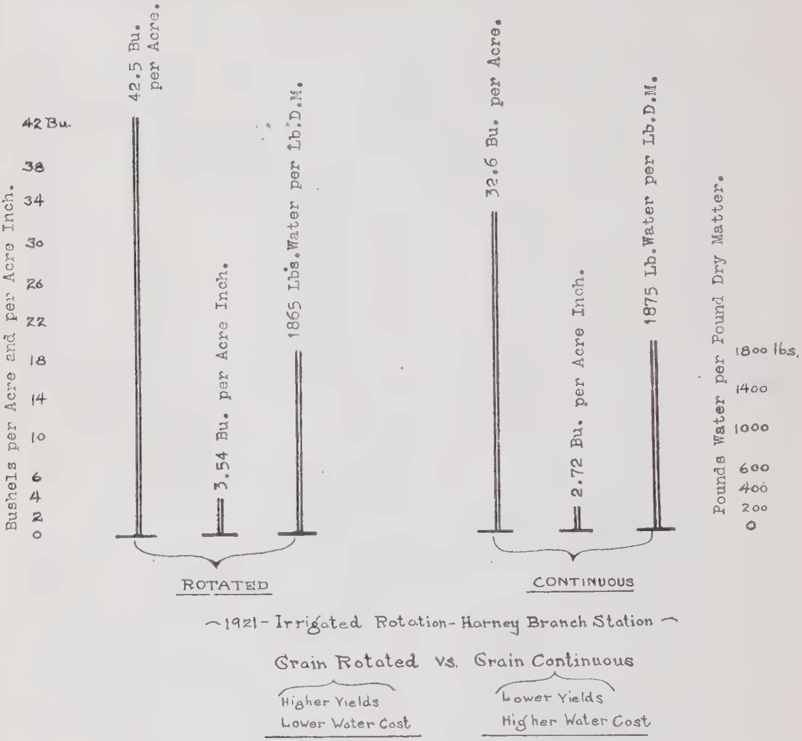

Fig. 15. Irrigated rotation, 1921, Burns Experiment Station.

TIME AND FREQUENCY OF IRRIGATION

The object of irrigation is to maintain a favorable supply of water for the crop through its period of development.

It is not possible to lay down any hard and fast rules for the irrigation of crops. The man who has handled crops to any extent will be able to tell from the general appearance of the crop, and condition of the soil, when to apply water. The crop should not be allowed to burn before water is applied as this will check growth to a marked extent. As a rule, when the plants have a dull green color and begin to droop, they are very near the danger point. Crops that have plenty of water have a bright green color and a thrifty appearance.

An excess amount of moisture will cause a rank straw growth at the expense of the yield of grain, will cause lodging and delay maturity. Over-irrigation prevents the proper circulation of air through the soil about the roots and causes the plants to turn yellow.

Frequent, light irrigations, are better than heavy irrigations at long intervals. The irrigation season should be shortened, depending on the locality, so that the crop will have time to mature before danger from fall frosts. Late irrigation delays maturity and causes a great deal of lodging.

DUTY OF WATER

While this experiment is still incomplete, the results to date warrant the recommendation of the following amounts of water for the crops listed below:

TABLE XV. SHOWING THE ACRE INCHES OF IRRIGATION GIVING THE BEST RESULTS AT THE BURNS STATION

Crop	Variety	Total acre inches of water applied to crop
Spring wheat	Federation	12
Winter wheat	Turkey 1558	12
Barley	Hannchen and Trebi	12
Oats	Rustless Selection	12
Spring rye	Vern, S. P. I. (26101)	12
Alfalfa	Grimm	18
Clover	White Sweet	15
Field peas	Kaiser	12
Sunflowers	Mammoth Russian	20
Combinations	Kaiser peas and Silvermine oats	2-15
Potatoes	Red pinkeye	10
Sugar beets	Sperling elite type A	12
Mangels	Half Sugar	12
Rutabagas		12

COMPARATIVE YIELDS OF DRY LAND AND IRRIGATED CROPS

The object of introducing this paragraph, and Table XVI, is to afford the prospective irrigator a working basis for a comparison of the two methods of farming. The results in this table represent average yields of two to five years, for the various crops grown.

TABLE XVI. SHOWS THE COMPARATIVE, AVERAGE YIELDS, OF DRY AND IRRIGATED CROPS, IN BUSHELS OR TONS PER ACRE, THE GAIN OF IRRIGATED OVER DRY LAND CROPS, AND THE NUMBER OF YEARS GROWN

Crop	—Yields, in bushels or tons per acre— Dry land	Irrigated	Years grown	Gain irrigation over dry land
Spring wheat	19.5	36.6	5	17.1 bu.
Winter wheat	13.0	49.0	3	36.0 bu.
Barley	16.1	52.5	5	36.0 bu.
Oats	18.2	59.8	5	31.1 bu.
Spring rye	15.4	20.7	4	5.3 bu.
Alfalfa (Grimm)	1.2	4.8	4	3.6 tons
Field peas	7.2	28.7	4	21.7 bu.
Sunflowers (silage)	23.0	54.4	2	31.4 tons
Potatoes	77.3	144.3	4	67.0 bu.

Note: Yields for the years 1917 and 1918 under irrigation, are abnormally low, due to heavy grading and do not represent the productive power of average Harney Valley soils.

THE COST OF IRRIGATION BY PUMPING

In order that the settlers in Harney Valley who are thinking about the installation of pumping plants, may have some basis for estimating the probable costs, the data on the plant at the Burns Station are herein presented.

The plant as it has been operated consists of one eight-inch well, drilled 218 feet deep, and cased down 100 feet from the surface. The pump is a 4-inch horizontal, centrifugal, and is located in the bottom of a pit about 8 feet from the surface of the ground. The intake is not fastened to the casing, direct, but extends down into the 8-inch casing, 20 feet, and is attached to the top of the casing with an air-tight collar. This pump is operated with an 8-horse-power gasoline engine.

The water is of semi-artesian flow and stands within five feet of the surface of the ground when the pump is not operating. When the pump is throwing ¾ of a second foot, the water stands at about 12 feet below the level of the pump.

In order to arrive at the actual cost of irrigation, by pumping, the subject must be considered in its several divisions. In this report, they will be handled under the following headings:

1. **First cost.** This includes drilling and casing the well, engine, pump, belt, retaining walls, and installation. The engine may be used for threshing and other purposes.

2. **Operating expenses.** This includes labor, fuel, and lubricating oil.

3. **Maintenance charges.** Covering interest on the first cost, depreciation (figuring that the entire plant except the well must be renewed in ten years), and repairs.

4. **Total annual cost.** This equals the sum of (2) and (3).

The cost, operating expenses, and maintenance charges of the Burns Station pumping plant are given below:

1. **First cost.**

Drilling well 218 feet	$ 298.00
Casing for well	391.32
4-inch centrifugal pump and belt	75.00
Installation of pump	60.00
8 Horse-power gasoline engine	240.00
Lumber for retaining walls and belt incline	10.00
Total first cost	$1074.32
First cost per acre	26.86

(Not including leveling and ditches which are considered fairly permanent land improvements.)

2. **Operating expenses.**

	Per hour
Labor @ $2.50 per day	$0.25
Fuel, 10 gal. (1 pt. per H. P. per hour)	.32
Lubricating oil (5 mills per hour)	.005
	.575

This plant will furnish ¾ of one second-foot, or will cover one acre 9 inches deep in 12 hours. To cover 40 acres one foot deep, it will take 640 hours, or 64 days of 10 hours.

3. Maintenance charges.

Interest on "First cost" of plant @ 6 percent	$ 64.46
Depreciation and repairs (replace plant in 10 years)	107.43

4. Total annual cost.

Fuel at 32c per hour, 10 hours, 64 days	$204.80
Labor at 25c per hour, 10 hours, 64 days	160.00
Lubrication, 5 mills per hour, 10 hours, 64 days	3.20
Total annual cost of irrigating 40 acres one foot deep	539.89
Cost per acre foot	13.50
Cost per acre foot per foot pumping lift	.60
Cost per acre inch	1.125

TABLE XVII. COST, VALUE, AND PROFIT FROM IRRIGATION

Crop	Ave gain irrig. over dry per acre (Table 16)	Value of gain per acre	Depth of irrig. (Table 15)	Irrig. total annual cost per acre	Net gain or loss per acre	Net gain or loss per acre inch
	T. or bu.		in.			
Spring wheat	17.1	$17.10	12	$13.50	$3.60	$0.30
Winter wheat	36.0	36.00	12	13.50	22.50	1.88
Barley	36.0	27.00	12	13.50	13.50	1.125
Oats	31.1	15.55	12	13.50	2.05	.17
Spring rye	5.3	5.30	12	13.50	8.20 loss	.68 loss
Alfalfa	3.6 T.	25.20	18	20.25	4.95	.28
Field peas	21.7 bu.	65.10	15	16.88	48.22	3.21
Sunflowers	31.4 T.	125.60	20	22.50	103.10	5.16
Potatoes	67.0 bu.	80.40	10	11.25	69.15	6.92

In Table XVII crop increases have been valued as follows:

Wheat and rye at $1.00 bushel; barley 75c bushel; oats 50c bushel; field peas $3.00 and potatoes $1.20 bushel. Alfalfa at $7.00 ton and sunflowers at $4.00. The high yield of sunflowers and low yield of potatoes causes the former to assume a high rank as to net profit from irrigation. This would be reduced if the value of fertility removed by sunflowers were deducted. Rye is found to be unprofitable at any reasonable price while field peas show a very good net return.

Net gain as figured here does not include original cost and maintenance cost of distribution ditches or preparation of land for irrigation, since these are considered fairly permanent improvements. Nor does it take into account the increase in cost of harvesting and marketing the increase in yield per acre. On the other hand, by irrigation a crop is produced each year, while under dry farming the land is in fallow one year out of two. There is more profit in large crops and fallow involves expense.

The figures given, therefore, are only an approximation to be used as a guide by the individual farmer until yields and costs are available over a longer period of years.

The following tables give the flow of water over weirs, and the time required for application of a given amount of water in irrigation.

APPENDIX

Table XVIII gives the flow of water over weirs in cubic feet per second.

TABLE XVIII. DISCHARGE OF STANDARD CIPPOLETTI AND STANDARD SUPPRESSED RECTANGULAR WEIRS IN CUBIC FEET PER SECOND

Head depth in inches	Head depth in feet	Width of weir in feet					
		1.0	1.5	2.0	2.5	3.0	4.0
	.20	.30	.45	.60	.75	.90	1.20
2½	.21	.32	.49	.65	.81	.97	1.30
	.22	.35	.52	.69	.87	1.04	1.39
2¾	.23	.37	.56	.74	.93	1.11	1.48
	.24	.40	.59	.79	.99	1.19	1.58
3	.25	.42	.63	.84	1.05	1.26	1.68
	.26	.45	.67	.89	1.11	1.34	1.78
3¼	.27	.47	.71	.94	1.18	1.42	1.89
	.28	.50	.75	1.00	1.25	1.50	1.99
3½	.29	.53	.79	1.05	1.32	1.58	2.10
	.30	.55	.83	1.11	1.39	1.66	2.21
3¾	.31	.58	.87	1.16	1.45	1.74	2.32
	.32	.61	.91	1.22	1.53	1.83	2.44
4	.33	.64	.96	1.28	1.60	1.91	2.56
	.34	.67	1.00	1.33	1.69	2.00	2.67
4¼	.35	.70	1.05	1.39	1.74	2.09	2.79
	.36	.73	1.09	1.45	1.82	2.18	2.91
4½	.37	.76	1.14	1.52	1.90	2.27	3.03
	.38	.79	1.18	1.58	1.98	2.37	3.15
	.39	.82	1.23	1.64	2.05	2.46	3.28
4¾	.40	.85	1.28	1.70	2.13	2.56	3.41
	.41	.88	1.33	1.77	2.21	2.65	3.53
5	.42	.92	1.37	1.83	2.29	2.75	3.66
	.43	.95	1.42	1.90	2.38	2.85	3.80
5¼	.44	.98	1.47	1.97	2.46	2.95	3.93
	.45	1.02	1.52	2.03	2.54	3.05	4.06
5½	.46	1.05	1.58	2.10	2.63	3.15	4.20
	.47	1.09	1.63	2.17	2.71	3.25	4.34
5¾	.48	1.12	1.68	2.24	2.80	3.36	4.48
	.49	1.16	1.73	2.31	2.89	3.46	4.62
6	.50	1.19	1.79	2.38	2.98	3.57	4.76
	.51	1.23	1.84	2.45	3.07	3.68	4.90
6¼	.52	1.26	1.89	2.52	3.16	3.79	5.05
	.53	1.30	1.95	2.60	3.25	3.90	5.20
6½	.54	1.34	2.00	2.67	3.34	4.01	5.34
	.55	1.37	2.06	2.75	3.44	4.12	5.49
6¾	.56	1.41	2.12	2.82	3.53	4.23	5.64
	.57	1.45	2.17	2.90	3.63	4.35	5.79
7	.58	1.49	2.23	2.97	3.72	4.46	5.95

The body of the table gives the flow in second-feet when given depths of water flow over weirs of various widths.

Example: A stream 4½ inches deep over a two-foot weir delivers 1.52 cubic feet per second.

The Management of Sandy Soils Under Irrigation. Oregon Agri. Col. Exp. Sta. Bulletin 177, by H. K. Dean.

Dup

Station Bulletin 192 November, 1922

Oregon Agricultural College

Experiment Station

Infectious Abortion of Cattle

By
B. T. SIMMS
and
FRED W. MILLER

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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SUMMARY

1. Infectious abortion is widespread in Oregon.

2. It causes at least 90 percent of all the abortions in this state.

3. Infectious abortion causes very serious loss to the dairy industry. It is a factor that brings financial disaster to hundreds of dairymen.

4. The germ which causes this disease lives in the fluids of the pregnant uterus and in the udder.

5. The infected cow is the principal source of the contagion. She is most dangerous at the time of calving or aborting.

6. Pregnant cows and heifers are very readily infected through pen or pasture exposure to aborting cows.

7. It has not been possible to spread the disease through the use of bulls which had served infected cows.

8. Heifers fed infected milk as calves will not carry the germs and abort after they are bred.

9. There are no diagnostic symptoms of abortion. Many infected animals give birth to live, vigorous calves. Such cows may be very active spreaders of the disease.

10. The disease can be diagnosed by a blood test.

11. No cure for abortion has been found. It is not even claimed that bacterins and vaccines will rid cows of this disease, but it is claimed they will prevent the act of abortion. They are still in the experimental stage.

12. With our present knowledge two methods of control and eradication are available. One is to test all animals, slaughter or sell all reactors, thoroughly clean and disinfect the premises, and develop a clean herd from the abortion-free animals. The other method is to test the herd, divide it into two parts, and keep the infected animals for breeding purposes. Extreme care must be exercised if this method is to be successful.

13. Owners of abortion-free herds should never introduce into their herds females that have not been blood tested. In buying new stock it is safest to procure young, unbred heifers.

14. A large amount of investigational work remains to be done with this disease. Cattle owners, investigators, and state livestock sanitary officials must cooperate in finally controlling infectious abortion.

Healthy looking cows, but more than sixty abortions followed their introduction into an abortion-free herd.

Infectious Abortion of Cattle

By B. T. SIMMS and F. W. MILLER

The investigational work reported in this bulletin was done with funds appropriated by the Oregon Legislature, in 1919 and 1921, at the request of the Oregon Dairy Association for investigation of diseases of dairy cattle.

Infectious or contagious abortion is a disease of cattle which is found in nearly all parts of the civilized world where considerable numbers of cattle are kept. It is more serious among dairy than beef animals but is quite prevalent among beef herds. Even under range conditions this disease has sometimes caused heavy losses.

In Oregon infectious abortion exists in practically every county. While not as prevalent here as in some of the older dairy states, it is spreading gradually. Several thousand tests conducted at the Experiment Station indicate that about 15 to 20 percent of all of the dairy cows in the state are infected. It has been found, moreover, that at least 90 percent of the aborting cows of this state are infected with this disease. Occasionally animals abort which are not infected, but they are relatively rare.

ECONOMIC LOSSES FROM ABORTION

During the past seven years the Veterinary Medicine department of the Oregon Agricultural Experiment Station has been collecting data concerning economic losses from infectious abortion. Some herds have been studied where owners have kept accurate records of all incomes, both before and after the introduction of this disease. In other herds individual records of all cows have been kept. By blood testing this type of herd it has been possible to compare income from both infected and abortion-free animals of approximately the same breeding which have been fed and handled in approximately the same manner. Such studies show that the losses may be the result of four different disturbances, all of which follow infectious abortion. These are abortion, sterility, garget, and decreased milk production.

Loss of Calf. Many owners believe the loss of the calf is the most serious result of abortion infection, but these studies have shown that even in well-bred registered herds the calf loss is the least serious of the four. The percentage of infected cows which abort varies greatly in different herds and in the same herd in different years. In some instances it is as high as 80 to 90 percent, while in others it may be as low as 5 percent or even less. It is difficult to form an estimate, but in these studies more than one-fourth of the infected cows have aborted. The value of each calf lost varies from practically nothing for scrub dairy calves to several hundred dollars for calves from high-producing registered dams.

Sterility so commonly accompanies abortion that many dairymen consider it as a symptom of the disease. Nearly every abortion-infected herd studied has had more or less sterility. These cases are almost always among the abortion-infected rather than among the abortion-free cows of the herd. The percentage of sterile cows has varied in different herds. A conservative estimate places the permanently sterile animals at 10 to 15 percent of all abortion-infected cows and the shy breeders at 15 to 20 percent of all infected animals. This means that abortion causes a minimum annual loss in Oregon of 5,000 to 7,000 sterile cows in addition to about 10,000 which are shy breeders. This represents a loss of nearly a million dollars annually.

Garget or mastitis has been much more prevalent in abortion-infected than in abortion-free animals. This trouble usually develops after cows have been infected for more than a year rather than at the beginning of an outbreak. It is not unusual to find a herd in which the percentage of abortion is decreasing while the diseases of the udder are increasing. One herd of 71 cows was blood tested and divided into two groups, there being 44 infected animals and 27 abortion-free animals. In a three-year period there were 31 cases of garget among the 44 infected cows while there were only 2 cases among the 27 abortion-free cows.

Decreased milk production is practically always noted in abortion-infected herds. Dairymen interviewed have usually reported a decrease of nearly one-half in milk production following outbreaks of abortion. Where accurate individual records of all cows have been available, this loss has varied from almost nothing to 100 percent in various cases, with an average of about 25 percent in the infected cows. These studies have included all cows infected, many of which have given birth to normal calves.

Estimating that 20 percent of Oregon cows are infected and that these average a loss of milk flow of approximately one-fourth, this indicates an annual loss in milk production of nearly one million dollars. The results of abortion disease alone are thus costing the livestock industry of Oregon more than two million dollars every year. This disease is bringing financial ruin to hundreds of dairymen each year.

CAUSE

The germ causing this disease is known as Bacillus abortus. It can be seen only with the aid of a microscope. All experiments indicate that this germ does not grow naturally outside the animal's body. It can be grown in laboratories, however, thus making it possible to study the germ under experimental conditions. It will live for several weeks to several months in yards, barns, etc. Exposure to dry air and sunlight hastens the death of the germ.

At the Oregon Experiment Station the abortion germ has been found in only two organs of the cow, namely the udder and the uterus. It has been found in the stomach, spleen, and other organs of aborted calves or living calves coming from abortion-infected dams. This infection will persist for months or even years in the udder, but in the uterus it disappears one to three months after calving.

The most serious source of these germs is the fluid in an infected pregnant uterus. This liquid is literally teeming with bacteria. They escape in large numbers with the calf whether there is an abortion or a live calf is born. The infection, moreover, continues to escape for several days to two or three months following aborting or calving.

Cows with infected udders give off these germs in their milk. An infected udder may pass germs from only one quarter, and it may pass germs in the milk only a part of the time. The amount of infection coming from the udder is relatively small when compared to that in the discharges from the uterus at the time of aborting or calving.

Calves born from infected cows may pass the germs in their dung for a few days. It is also possible that calves fed abortion-infected milk will continue to void these bacteria in the dung as long as such milk is consumed.

Some investigators have found a few bulls which were infected. Such animals may have abortion germs in their testicles and may pass them out in the semen. Abortion-infected bulls are very scarce in Oregon. The Experiment Station has not found any bull which throws off the infection in this manner.

METHODS OF SPREAD

An extended study of the methods of spread of abortion has been made. Various dairymen and investigators have claimed that the trouble is spread by the bull at service, through infection of calves by infected dams before birth, through feeding infected milk to calves, through pen or pasture exposure of unbred heifers to aborting cows, and through pen or pasture exposure of pregnant heifers or cows to aborting animals. All of these have been tested at the Oregon Experiment Station.

Bulls Have Not Spread Abortion. Approximately fifteen bulls have been used in a study of the possibility of the spread of the disease through the bull at service. These have been bred to cows which had aborted and then to abortion-free cows or heifers. In some instances bulls were bred during the morning to a cow which had aborted and during the afternoon to sound heifers. All told, more than 100 calves had been sired by these bulls. In no instance has there been any evidence obtained that the bull has spread the disease.

Abortion Is Not Inherited. The possibility of calves from infected dams becoming infected before birth has been studied by observing both heifers and bulls born from infected cows. Such calves have not inherited the infection. If they are fed milk from their dams they will frequently give positive blood tests during the first few months of their lives, but if this milk is discontinued before the sixth or seventh month the blood test changes to negative. If such heifers are not exposed later in life they remain negative to blood tests and give birth to normal calves.

Heifer Calves Are Not Infected By Drinking Infected Milk. More than 90 heifers have been used in studying the possibility of spreading abortion through feeding infected milk. These heifers have been fed raw milk from an abortion-infected herd. This milk has been tested at intervals for abortion germs by injecting guinea pigs. Such tests have shown that the infection has been present. All these heifers have remained negative to blood tests and have given birth to normal calves, if they were not exposed after the milk feeding period had passed.

Unbred Heifers Are Not Easily Infected. Pen and pasture exposure of unbred heifers has been studied by using animals between the ages of 7 and 18 months. They have been penned and pastured with aborting cows. Monthly blood tests have been made on these to determine whether they became infected. Only a small percentage have changed from negative to positive blood tests. It has been noted, though, that as the heifers grow older and the udder tissue increases in amount they may become slightly more susceptible. In cases of infection in this manner the bacteria very probably become localized in the udder.

Pregnant Cows and Heifers Are Easily Infected. Many experiments with pregnant heifers and cows have been conducted. The first one of these consisted in using eight pregnant heifers. They were penned with three cows which aborted while with them. Five of these heifers aborted. Further experiments showed that it is very easy to infect pregnant animals through penning or pasturing them with abortion-infected cows.

Infection Enters the Body Through the Mouth. In an effort to determine how the bacteria enter the body of the susceptible animals, pregnant cows have been given abortion germs in water through their digestive tract. Cows used in this experiment have been negative to blood tests before the experimental work began. They have changed to positive blood tests and have either aborted or given birth to weak premature calves. The germs have been found in the stomachs of calves aborted by these cows. These experiments have shown that it is easy to infect pregnant cows by giving the germs through the digestive system. Such experiments, moreover, have been successful even as late as the seventh month of pregnancy.

Cleaning Stalls Without Disinfecting Them Is Not Satisfactory. In still another test two cows were allowed to abort in a stall. This stall was cleaned out down to the concrete floor but was not disinfected. After a week had passed a negative cow was placed in the stall. This cow changed to positive in less than one month and aborted.

SYMPTOMS

There are no absolutely positive symptoms of abortion. The most generally recognized symptom is the act of abortion. It is true, though, that many infected animals give birth to apparently normal calves. Such cows may be very dangerous as spreaders of the disease, though they themselves carry their calves full time. In animals which do lose their calves the loss may occur any time during pregnancy. At this Experiment Station cows have been observed to abort as early as the seventh week and as late as the middle of the ninth month of pregnancy. Many dairymen say cows do not abort before the fifth month. Up to this period, however, calves are so small that they are not seen when aborted.

Retained after-birth or failure to clean is another very common symptom in infected cows. This follows both abortion and delivery of live calves, but this trouble is sometimes quite prevalent in herds not infected with abortion.

Studies at this Station have shown that sterility, enlarged joints, garget, and lessened milk production are very frequent in infected cows. Since these troubles are occasionally seen where abortion is not present it is not possible to make a positive diagnosis by observing them. As stated above there are no symptoms by which a high percentage of abortion-infected cows can be detected.

METHODS OF DIAGNOSIS

Two laboratory blood tests for diagnosing this disease have been found by investigators to be satisfactory. These are the agglutination test and the complement fixation test. Of these the agglutination is the simpler and in the hands of most investigators has been just as satisfactory. This is the test used at the Oregon Experiment Station. After running several thousand of these blood tests it seems to be as accurate as any of the tests for disease. It will not foretell an abortion, but it will detect the abortion-infected cows. Animals infected experimentally usually react in two to six weeks after they are given the organism.

This test is conducted in the following manner. Blood is collected from the jugular vein of the cow to be tested and set aside in a cool place until it clots. As the clot grows older it contracts and squeezes out a clear liquid called serum. In the laboratory the abortion germs are grown and then suspended in a weak salt solution. Enough germs are placed in this solution to make it slightly cloudy. Measured amounts of this suspension are then placed in test tubes, three tubes usually being prepared for each animal that is to be tested. Then serum is added in such quantities that the first tube will contain 1 part of serum to 50 parts of bacterial suspension; the second tube, 1 part of serum to 100 parts suspension; and the third tube, 1 part to 200. The tubes are stored in a dark place and examined at the end of the third day. If a cow is infected her serum will cause the bacteria to agglutinate or clump together. These clumped germs will settle to the bottom, leaving a clear solution. If a cow is not infected her serum will have no influence and the bacterial suspension will remain cloudy.

In some cases a diagnosis can be made by finding the abortion germs either in the milk or in the uterine discharges. This is usually done by injecting guinea pigs and producing the disease in them. This method is too slow and too expensive ever to come into general use.

DURATION AND OUTCOME

Infectious abortion is essentially a chronic disease. Some cows under observation at this Experiment Station now have been infected for more than six years. While infection usually disappears from the uterus a few weeks after calving or aborting it remains more or less permanent in the udder. It is probably true that some animals do make complete recovery, but studies at this Station indicate that this is relatively rare in dairy cows. It is a mistaken idea that cows will abort only once or twice and then become immune. Many cows abort the third time. Two cows under study now have aborted five times each. Dairymen have learned from experience that aborting cows are many times shy breeders. It has become a general practice, therefore, to sell any cow that aborts a second time. This is one reason that cows that have aborted three or more times are not very plentiful.

The course and severity of the disease vary greatly in different herds. In some outbreaks half to two-thirds of the pregnant animals may abort one year and only 5 to 10 percent abort the next time. Some herds have been studied in which abortions were very numerous one year, while the following season all cows carried their calves full time only to have quite a number of abortions in the next pregnancy. Other herds under observation have had heavy losses annually for six or seven years in succession with no material decrease.

Data collected indicate possibly some relation between the method of handling a herd and the course of an outbreak. In those herds that are bred so that all the cows freshen during one season, outbreaks are many times very severe, but frequently the percentage of abortions occuring in the following year is quite low. On the other hand herds that are bred so that some cows freshen each month frequently have a less severe initial outbreak but a higher percentage of abortions in the following year. More data on this are being collected.

TREATMENT

No method of curing abortion infection is known. Many remedies have been recommended but none of them have stood the test of time. The claim that various forms of lime salts will cure the trouble has not been proved. It is a significant fact that abortion is very common in those sections of the country where the soils contain large amounts of lime and where the foods generally used are those relatively high in this substance. Administration of drugs seems to have no influence in the course of abortion. An occasional cow probably makes a complete recovery, but such animals are rare in the herds studied by this Station. The only safe procedure is to consider that once infected means always infected unless there is definite proof to the contrary.

Abortion bacterins and vaccines have been widely advertised and used during the past few years. The bacterin is a suspension of dead abortion bacteria in a weak salt solution, while the vaccine is a suspension of live abortion germs in a salt solution. It is interesting to note that the various investigators that have recommended these substances differ very widely in size of doses, number of doses necessary to produce immunity, etc. Abortion varies so much in different herds that it is very difficult to interpret results following these injections. Some investigators have reported excellent results, while others have failed to find any virtue in either the bacterin or the vaccine. As a matter of fact these are not yet beyond the experimental stage. The Oregon Station has begun a rather limited study of the vaccines, but it will take several years to obtain definite proof that this is either valuable or worthless.

It should be borne in mind that neither the bacterin nor the vaccine is supposed to rid cattle of abortion infection. They are used with the hope that they will increase the resistance and enable the injected animals to carry their calves to maturity.

Furthermore, the use of the vaccine may result in establishing infection in clean animals. It should therefore be used very cautiously and only in unbred animals which will very probably be exposed to the infection during pregnancy. Cattle owners should not be deceived by offers to guarantee results. These substances are sold at very substantial profit, and manufacturers can afford to reimburse a goodly percentage of their customers and still make a profit on the production cost.

METHODS OF CONTROL AND ERADICATION

Since no method of curing infectious abortion has been found, it is all the more necessary that methods of control and eradication be worked out. At the Oregon Experiment Station all investigational work with this disease has been planned and carried out with this end in view.

Non-Infected Herds. In considering control all herds may be divided into two groups, those not infected and those infected. Every dairyman whose herd is free from the disease should take every precaution to keep this most serious trouble out of his herd. He should be just as careful concerning this disease as he is concerning tuberculosis. No new animals should be brought into the herd without a blood test being made before they are allowed to mingle with the herd; then there should be a second test after 60 days. Stray cows and heifers should be kept out of pastures, barn lots, etc., in which the abortion-free animals are kept. A rather common method of spread consists in pasturing pregnant heifers and dry cows of an entire neighborhood in a single pasture. Under such conditions a single infected cow may spread the disease to a large number of herds.

Infected Herds. The infected herd presents a far more difficult problem. At the Oregon Experiment Station two methods of handling such herds are being studied. One consists in blood testing all cattle, selling off all reactors, thoroughly cleaning and disinfecting the barn, and then retesting every 30 to 60 days until the herd has passed at least three tests. This method has been tried out sufficiently to show that it will give results under some conditions. Not enough data have been accumulated, as yet, to be sure that this will be successful in every section and under all systems of herd management. This is the method recommended for all herds showing less than 8 to 10 percent reactors and in most herds into which the disease has been introduced very recently. Such a procedure may seem very drastic, but figures collected show that abortion-infected cows are usually money losers. The sooner they go for beef, therefore, the better off the owner will probably be. After a herd is once free, of course every precaution must be taken to keep it clean.

The second method is a far more difficult one. It consists in blood testing the entire herd, separating the infected animals from those not infected, and keeping the infected cows separate until a sufficient number of non-reacting heifers have been raised to fill the herd. This involves the maintenance of a rather rigid quarantine. Garget, sterility, and lessened milk production frequently appear to such an extent among the infected animals that they are money losers, but in high-priced pure-bred herds such a method of control of abortion and reestablishment of abortion-free herds may be warranted. This method of control is still in the experimental stage. It has given satisfactory results in some herds, but only in those owned by men who would keep the infected cows absolutely separate from the sound ones. The expenses of following this plan are so great that it can be used economically only in herds of good cattle.

No economical method of eradicating abortion from badly infected herds of common cattle has been found. Perhaps vaccination may increase the resistance of these animals to some extent, but as stated elsewhere the vaccines are still in the experimental stage. With the present knowledge of the disease it seems advisable to sell any grade herd in which the disease has become so severe that the animals are losing money for the owner.

QUARANTINE AND STATE REGULATIONS

Many owners have urged that the State Livestock Sanitary Board through the office of State Veterinarian should take control of infectious abortion and handle it similarly to present methods of handling tuberculosis. They have believed that infected herds should be quarantined, that blood tests should be required of all animals offered for sale at public auction, and of all animals exhibited at state fairs, and that no cattle should be brought into the state for breeding purposes unless they have been tested and found free from contagious abortion.

The time does not seem to be ripe for such drastic action as yet. A great deal is still unknown concerning this disease. The percentage of infected cattle is very high, and cattle owners are not as yet awake to the seriousness of contagious abortion. Before quarantines can be established and state control can be undertaken, a large amount of investigational work must be done. The livestock owners, too, must be thoroughly informed as to the economic losses caused by this disease. At the present time at least, each owner must be very largely his own sanitary and quarantine officer.

THE FUTURE

Contagious abortion is becoming more widespread and more serious as time goes on. Its ravages must be checked or it will bring financial ruin to increasing numbers of cattle owners. In order that this may be accomplished all forces concerned must band together for the fight. The investigators must push forward finding new truths, making new discoveries, and working out new methods of applying them. Individual dairymen and beef producers and all dairy and beef associations must support the Experiment Station in doing this work. The progressive dairymen and beef producers must educate the less progressive to the dangers of the trouble. As soon as investigations and educational work have made such action possible, state livestock sanitary officials must take proper steps toward control and eradication. Perhaps abortion-free, accredited herds can be established. Then abortion-free areas and finally abortion-free counties may ultimately be realized. Such results can only come through continuous and increased cooperation of investigator, livestock owner, and livestock sanitary official. It will be a long fight and a hard one, but the victory will be well worth all the effort.

This opportunity is taken to thank the various cattle owners of the state who have cooperated with the Experiment Station in the work. Acknowledgment is also made of the admirable cooperation given at all times by the Dairy Husbandry department of the College.

compliments of
the Author

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Oregon Agricultural College

Experiment Station

Eastern Oregon Branch Station

Fattening Steers

(1922 EDITION)

By

E. L. POTTER and ROBERT WITHYCOMBE

CORVALLIS, OREGON

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FEED LOTS, EASTERN OREGON BRANCH EXPERIMENT STATION

SUMMARY

Alfalfa Hay alone produced a daily gain of .97 pound when fed to two-year-old steers. The steers were given a daily ration of 37 pounds, of which they refused 5 pounds.

Chopping Alfalfa Hay for fattening steers increased the gains and saved waste. One ton of chopped hay made 13 percent more gain than one ton of long hay. The cost of chopping in these tests was about $3.00 a ton. Under normal conditions this amounts to more than the increased value of the chopped hay.

Alfalfa Hay and Grain produced 30 percent more daily gain than hay alone. One pound of rolled barley replaced three pounds of alfalfa hay. It made but little difference whether a small ration of grain was fed throughout the entire feeding period or a heavy feed of grain during the latter part of the period.

Alfalfa Hay and Silage produced 64 percent more gain than hay alone, while the daily feed cost was approximately the same. The steers fed hay and silage were fatter and dressed out more than those fed hay alone. Alfalfa hay and corn silage, or peas and barley silage, make the most economical and satisfactory ration for fattening two-year-old steers for the Western market.

Meadow Pasture produced a daily gain of 1 pound during the first month, 2.39 pounds the second month, 2.31 pounds the third month, and .7 pound the fourth month. Steers finished on pasture topped the market.

Management of Fattening Steers to produce good gains requires that one handle the cattle gently, make feed-yard conditions comfortable, use a good quality of feed stuffs, feed regularly, use care in the selection of the feeder cattle, and feed nothing but good, thrifty individuals of beef breeding.

Fattening Steers

By

E. L. POTTER and ROBERT WITHYCOMBE

INTRODUCTION

(This bulletin is a revision of Bulletin No. 174 published in August, 1920, and which is now out of print. This publication includes all of the data from Bulletin No. 174, together with additional data from experiments conducted between August, 1920, and August, 1922.)

At the time this work was first planned (1912) the general practice of fattening cattle during the winter months throughout the Northwest was on hay alone. Very few farms were equipped with stock scales, hence the feeders had but a very hazy idea of the gains actually made or the cost of gain. With a view to investigating this whole problem a series of tests was inaugurated at the Eastern Oregon Branch Experiment Station at Union, Oregon.

The Union Station includes 620 acres of land in addition to rented range and pastures. Its location is typical of the higher, cooler valleys of the Blue Mountain and Rocky Mountain regions. The winters are cold and windy. The lots in which the tests were conducted were without shelter other than a six-foot board fence around one corner which served as a windbreak. The lots were 90 by 230 feet and accommodated 25 steers to the lot for the first two years. Then they were divided into lots 45 by 115 feet and used to accommodate 10 to 12 steers each. Water from a small stream was diverted through the lots by means of a wooden trough. This trough carried a stream of water one foot wide and about eight inches deep, which flowed rapidly enough to give little difficulty from freezing except in extreme weather.

The feeds used were all produced at the Station. The alfalfa hay was cured and stacked in the field as carefully as possible, but of course varied in quality from year to year. It was all fed, however, just as it came. In our judgment it was fairly representative of the class of hay generally used in the Northwest for steer-feeding purposes. The corn used for silage had been frosted and was usually put into the silo before it was quite mature. The mixture of peas and bald barley was in very good condition and made a very good quality of silage. As a whole, however, the quality of the silage was certainly not above average and perhaps a little below. The chopped hay was prepared by running the alfalfa through a cutter, which cut it from one-fourth to one inch in length. During the last two years the hay was hauled from the field in the fall, chopped, and blown into a barn. Previous to that the hay was chopped in the field.

The cattle used were two-year-old steers varying in weight in different years from 928 to 1100 pounds at the beginning of the tests. They were representative of the steers generally used in the Northwest for feeding purposes. They were not fancy but were fairly free from dairy or scrub blood. Each animal was branded with a serial number when first placed in the feed yards and individual weights were taken of all the cattle at the beginning and end of each test. The lots were weighed also at the close of each thirty-day period. Much detail has been omitted in this bulletin, however, in order that the discussion might be reasonably brief and readable. The tables are nearly all averages of several tests. The omitted data, however, are all on file in the office of the Eastern Oregon Branch Experiment Station, and may be obtained on request.

PART I. COMPARISON OF HAYS

Our first year's work was a comparison of the three different kinds of hay. Seventy-three head of two- and three-year-old grade Hereford steers, part native and part Utah cattle, were divided into three lots, twenty-five in each of the first two and twenty-three in the third.

The alfalfa hay was of poor quality, and the bald barley hay was coarse and too well matured to make good cattle feed. The wild hay, however, was quite typical of the hay harvested from our native meadows in this section.

Since there was some grain in the bald barley hay, eighteen pigs were allowed to follow the cattle in Lot. 2. These pigs averaged 80.5 pounds at the time they were placed in the yard, January 4, 1914. At the close of the test, April 11, 1914, they averaged 94.4 pounds, showing an increase in weight of 13.9 pounds a head.

TABLE I. ALFALFA HAY, BALD BARLEY, AND WILD HAY

Lot 1, 25 steers fed alfalfa hay
Lot 2, 25 steers fed bald barley hay
Lot 3, 23 steers fed wild hay

Feeding period—December 27, 1913 to April 11, 1914—105 days

Lot No.	Weight at beginning	Weight at close	Daily gain	Daily ration
	lbs.	lbs.	lbs.	lbs.
1	968	1071	0.99	38.8
2	1032	1060	0.27	36.4
3	1066	1112	0.44	30.7

From the results given in Table I, it will be noticed that the cattle in Lot 1 on alfalfa hay made a very satisfactory gain, while those in Lots 2 and 3 did not do so well.

The steers in Lot 1 were given an average of 39 pounds of alfalfa hay a day and made an average daily gain of .99 pound. Those in Lot 2 received 36 pounds of bald barley hay a day and made an average daily gain of .27 pound. The steers in Lot 3 were given 31 pounds of wild hay and made an average gain of .44 pound a day.

While these cattle were in very good flesh at the close of the winter feeding period, yet they did not have enough finish to justify putting them on the market; hence the 73 head averaging 1076 pounds were turned out on good meadow pasture April 11, 1914. The results of the gains made while on pasture are given later in Part V, pp. 12-13.

No further work was done with bald barley hay or wild hay, but during subsequent years several other lots were fed on alfalfa hay alone.

The results of all these tests with alfalfa hay alone, excluding those fed chopped hay, are shown in the following summary:

Weight at beginning	1039 lbs.
Weight at close	1155 lbs.
Daily gain	.97 lb.
Daily ration—	
Hay offered	37 lbs.
Hay refused	5 lbs.
Hay consumed	32 lbs.

The daily gain shown above is not as large as is claimed by many feeders, but it is a true average of our results for two-year-old steers. The calves and yearlings we have fed have done slightly better than this, and if they were averaged along with the two-year-olds the average would be 1.00 pound a day. Of course gains vary greatly. There are authenticated instances where steers on alfalfa alone have gained 2 pounds a day and other cases where good steers on good hay have made no gain.

The information we have been able to gather from experienced feeders corresponds closely with the figures obtained at the Experiment Station, and we feel quite certain that the average gain on alfalfa-fed cattle one year with another and without counting any fill is just about one pound a day.

PART II. COMPARISON OF HAY AND GRAIN

Since we were looking for something better than alfalfa alone, and not something inferior, the next step was to try alfalfa alone against alfalfa with five pounds of barley a day and also alfalfa alone for the first sixty days with the addition of ten pounds of barley during the last sixty days. The test started with a car-load of steers in each lot. During the second and third years, however, each of these lots was divided and one half fed long hay and the other cut hay. The results of the work for three years are combined and summarized in Table II.

TABLE II. ALFALFA HAY AND GRAIN

A summary of three years' work—1915, 1916, and 1917. The results include data for 217 head of cattle, fed 120 days.

Lot 1, Alfalfa hay.

Lot 2, Alfalfa hay and 5 pounds rolled barley.

Lot 3, Alfalfa hay and 10 pounds rolled barley during last half of the feeding period.

				Daily ration			
Lot No.	Weight at beginning	Weight at close	Daily gain	Alf. hay Offered	Alf. hay Refused	Alf. hay Eaten	Rolled barley
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	1088	1200	0.92	36.23	3.99	32.51	......
2	1090	1239	1.24	32.72	3.77	28.95	4.80
3	1091	1231	1.17	31.21	3.50	27.69	*8.72

*For half of the time only.

The steers on hay alone gained .92 pound; those on hay and 5 pounds of barley gained 1.24 pounds; and those on hay with 10 pounds of barley during the last half of the feeding period gained 1.17 pounds a day. The difference in finish was hardly noticeable and none of the lots were in good marketing condition at the end of the 120 days' feeding.

The steers in Lot 3 made slightly less gain than those in Lot 2, but since there were a few steers in Lot 3 that were not very good feeders, we believe that it really makes very little difference whether barley is fed at the rate of 5 pounds a day from the beginning or whether it is saved until the last half and then fed at the rate of 10 pounds a day.

A study of the amount of feed required to produce 100 pounds of gain shows that one pound of rolled barley took the place of three pounds of alfalfa hay. The economy of feeding this small barley ration would therefore depend upon whether one pound of barley costs more or less than three pounds of alfalfa hay.

PART III. COMPARISON OF CHOPPED HAY WITH LONG HAY

In 1916 and again in 1917 chopped alfalfa was compared with long alfalfa in three ways: (1) Hay alone; (2) Hay with 5 pounds of rolled barley a day; (3) Hay with 10 pounds of barley during the last half of the feeding period. Since methods (2) and (3) gave results similar to those described in Part II, these lots are averaged together in our summaries.

In 1918 and also in 1919 chopped hay was compared with long hay when fed in combination with silage instead of with rolled barley. The results of all these tests are summarized in Table III.

TABLE III. LONG ALFALFA AND CHOPPED ALFALFA HAY

Lot 1, Long hay.
Lot 2, Chopped hay.

Averages of two years' results

Lot No.	Weight at beginning	Weight at close	Daily gain	Daily ration		
				Offered	Refused	Eaten
			A. When fed alone			
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	1042	1137	0.79	34.15	4.16	29.97
2	1042	1179	1.15	34.50	1.31	33.20
	B. When fed with an average ration of 4.67 pounds of rolled barley					
1	1042	1192	1.25	30.48	4.02	26.46
2	1042	1209	1.39	29.58	1.19	28.39
	C. When fed with silage (24.88 to Lot 1, and 21.92 to Lot 2)					
1	1026	1179	2.02	23.25	2.44	20.81
2	1036	1191	2.07	23.93	0.99	22.95

In case of the hay fed alone the improvement brought about by cutting was quite marked. The steers fed chopped hay made a daily gain of .36 pound more, ate 3.23 pounds more, and refused 2.85 pounds less hay than did those which were fed long hay. This difference in daily gain, however, is possibly a little greater than should be expected normally, and was due probably to heavy snow drifting into one of the long hay lots. The steers in this particular lot made a daily gain of .66 pound, whereas the average gain made by all the lots on long hay was .97 pound. From these tests it would appear that the value of the hay fed alone was increased 43 percent by chopping, but if the long-hay lots had all made normal gains the improvement would have been only 18 percent. This we believe to be more nearly the correct figure.

When fed with a small grain ration the steers on chopped hay consumed 1.93 pounds more, refused 2.83 pounds less, and gained .14 pound more than did those on long hay, an improvement of 14 percent. When fed silage the steers on cut hay made slightly greater gains on a little less feed; but the difference was less marked than when fed cut hay alone or with grain, and the actual improvement amounted to only 7 percent. The average improvement from chopping in these experiments would therefore be 13 percent. The Idaho Experiment Station in similar tests obtained better results with chopped hay when fed with grain or silage but poorer results when fed alone than those secured at the Union Station. The average of their tests with fattening steers showed an improvement in value of 21 percent, while with lambs, chopping, for some reason, failed to effect any improvement whatever. The improvement due to chopping will naturally vary with the quality of the hay and the way in which it is handled. It is quite safe to say, however, that chopping will save waste, will make larger gains, and will require less feed per 100 pounds gain. The actual improvement will be probably between 10 and 20 percent.

VISITORS INSPECTING SILAGE-FED CATTLE

So far we have discussed only the effect of chopping on the feeding value of the hay without considering the costs. The following statement shows the cost at the Experiment Station in 1919 of chopping 60.1 tons of hay.

2 men and 2 teams 5 days @ $8.00 a day	$80.00
2 men 5 days @ $5.00 a day	50.00
1 man 1¼ days @ $5.00 a day	6.25
Gasoline 30 gal. @ 34c	10.20
Distillate 60 gal. @ 22c	13.20
Cylinder oil 3 gal @ $1.10	3.30
Machine oil 3 gal. @ 65c	1.95
Hard oil 5 lb. 85c a pail	.85
Total cost	$165.75
Cost per ton	2.75

Power used, 15x27 Gas Tractor.
Cutter used, 20 in.

In the above account no charge has been made for interest or depreciation on machinery. These figures should, of course, be included in the cost, but since our engine was bought for other purposes and the cutter used also for cutting silage, we have no accurate data on interest and depreciation. The expense items listed, however, are quite accurate. The machinery was in good order. The men were busy. With a larger machine the labor costs might be somewhat lessened; with smaller machinery or with machinery not in good running order the labor costs would be higher.

Comparing these figures with the feeding results given above it will be seen that it is only under rare conditions that chopping will pay its cost.

PART IV. ALFALFA HAY AND SILAGE

While rations of alfalfa hay and a small amount of grain, as well as chopped alfalfa, gave somewhat larger gains than were obtained from the feeding of long alfalfa alone, yet the increased gains were not sufficient to make much difference in the final finish of the cattle, and furthermore the cost of production was in most cases increased. We were looking for something that would give more finish and more rapid gains than we had been getting from the feeding of the above rations without going to the expense of feeding a full grain ration. This led us to try silage along with the alfalfa. Our first test was in the winter of 1916-17 and included only one lot. The results were so good that we could scarcely believe the figures. We therefore continued the work on a more extensive scale. Five lots have been fed on hay and silage with the results shown in Table IV.

TABLE IV. ALFALFA HAY AND SILAGE

Lot 1, Alfalfa hay.
Lot 2, Alfalfa hay and 23.7 lbs. silage.

Lot No.	Weight at beginning	Weight at close	Daily gain	Daily ration Offered	Daily ration Refused	Daily ration Eaten
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	1039	1158	1.02	35.6	3.9	31.7
2	987	1151	1.67	22.8	2.8	20.0

The results given in Lot 1 comprise an average of seven tests and include experimental data for 108 steers; those in Lot 2, ten tests and 110 steers. Twenty-four cattle in Lot 1 and twenty-three in Lot 2 received chopped hay. All others received long hay.

Table IV speaks for itself. The hay-and-silage cattle made 60 percent more gain than was made by the cattle fed hay alone. The cattle were all well filled before the tests began so there is no fill involved. The silage-fed cattle not only made larger gains as shown by the scale weights, but they took on a much better finish and looked better in every way. At the end of the tests, the cattle which had received a ration of hay and silage were in good killing condition and ready for market, while those on hay alone were not, and required a further finishing on pasture. (See Part V, pp. 12-13.)

It will be noted that each pound of silage fed reduced the amount of hay fed approximately one-half pound. Lot 2 receiving 23.7 pounds of silage received 13 pounds less hay. At $7.50 a ton for hay and $6.00 a ton for silage the daily feed cost of Lot 1 was 13⅓ cents and of Lot 2, 15⅔ cents. This would amount to $2.78 a head on a four months' feed. In other words the cost per day is increased very little with hay and silage over hay alone, but the gains are 64 percent greater and of course correspondingly cheaper. The real financial meaning of this is shown by the fact that a 1000-pound steer costing 7 cents, fed for 120 days on hay alone and sold for 8 cents would return $7.63 a ton for the hay after paying all expenses including interest and labor. Under similar conditions a steer fed hay and silage would return $8.73 a ton for the hay, $6.58 for the silage. In reality, however, the silage-fed steer would be a better steer than the hay-fed steer, and if the former brought 8 cents the latter would at least bring a quarter more, in which case he would return $9.44 a ton for the hay and $7.57 for the silage above all expenses.

It is often assumed that cattle fed on silage will not dress out well and that they shrink badly going to market. We have conducted but one experiment planned to throw any light on this question. The results were as follows:

TABLE V. SELLING PRICES OF SILAGE-FED AND HAY-FED CATTLE

Method of feeding	Shrink Union to Portland	Dressing percentage	Selling price
	lbs.	%	
Hay alone	44.0	55.1	$7.86
Hay and light feed of silage	24.4	57.0	7.85
Hay and full feed of silage	28.3	57.0	8.12
Hay and silage for 120 days and hay and barley for last 30 days	33.5	57.7	8.44
Hay and silage for 75 days and hay and barley for last 75 days	34.3	59.9	8.40
Hay and silage together with 5 pounds of barley for entire 150 days	32.5	60.6	8.65

From this test it will be seen that the silage-fed cattle were fatter and dressed out better than those fed hay alone. Those having had grain were still fatter and gave a better dressing percentage. The more grain they had the better they were, of course. The cattle were sold to Swift and Company, and each lot was appraised without knowledge of how they had been fed.

The shrinkage en route to Portland seemed to follow no regular rule, but the silage lots certainly showed up well. The shrinkage for all lots was lower than what we usually expect on such shipments.

Further tests along these lines will be necessary, but we can be sure that silage makes fatter cattle than hay alone and that the cattle dress out better. We cannot, of course, expect cattle fed only silage and hay to be as fat as cattle receiving a grain ration, but they can be made good enough for the Western markets. The question of economy and profit of using grain to finish steers fattened largely on silage and hay seems to depend on the relative prices of hay, silage, and grain, and there was nothing in this test to disprove the conclusions of Part II; that is, that one pound of rolled barley is worth three pounds of alfalfa for fattening steers.

The amount of silage fed varied in different lots from 10 to 34 pounds a day. There is so far no conclusive evidence that the rate of gain is affected by the amount of silage fed providing it is within these limits. When the silage portion of the ration is decreased, the cattle, of course, consume more hay. Our results with the lighter feed of silage so far, have been rather less satisfactory than where the larger amounts were fed, but the Idaho station obtained the opposite result so we will have to withhold conclusions until we make further tests.

It has been our practice to feed the silage in bunks the same as grain. The silage was weighed and fed in quantities that the cattle would clean up without waste. In every case, however, they were given all the alfalfa hay they would eat even at the expense of a little waste.

In general, we believe that cattle fatten so much better on hay and silage than on hay alone that it will be but a short time until the greater portion of the cattle fattened in the Northwest during the winter months are fed on hay and silage and that the man who attempts to fatten cattle on hay alone is working against an impossible handicap.

Some may say that the ranchman cannot make as good gains as the Experiment Station, but this is not the case. The cattle used in these tests were average feeders such as can be bought anywhere; in fact, on two different years feeders were hard to buy and we had to use some inferior cattle that did not make satisfactory gains. Our feed lots are cold and badly exposed. Our hay was average, but the silage on account of frost was rather below average. It is our judgment, therefore, that in general the farmers will obtain rather better results than those shown in this bulletin. Not many cattle have been fattened on hay and silage in Oregon; but there are a good many fed in this way in Idaho and Colorado, and the feeders in those states are getting slightly better results than those quoted, usually around 1¾ pounds on hay and silage and 1 to 1¼ pounds on hay alone.

It must be borne in mind, however, that the figures given here are for fattening two-year-old steers. The use of silage for wintering stock cattle has been made the subject of other tests, and it may be stated that thus far silage for stock cattle has not given such phenomenal results as are shown for fattening purposes; nevertheless it has proved to be a very satisfactory feed.

PART V. FINISHING ON PASTURE

In our discussion of fattening steers we have stated that with the exception of those fattened on hay and silage the steers were not really in marketable condition at the end of the tests. At the close of the winter feeding period, in order to give them more finish, the steers were turned out on alfalfa and blue-grass pasture. This pasture consisted of a rather uneven and spotted piece of meadow land, the better portion of which had at one time been seeded to alfalfa but had largely gone to blue-grass and other grasses. For three seasons this piece of meadow pasture was used to finish the cattle, which had been on feed during the preceding winters at the Station.

In 1914 all of the seventy-three steers that had been fed on various hay rations the preceding winter were turned out on grass April 11. In 1915 all of the seventy-five head that had been fed on hay alone, and on hay and small barley rations, were turned out April 18. In 1916 the best twenty-four head were shipped to Portland at the close of the winter feeding period, and the remaining forty-eight head were turned out April 25. Some of the steers had received hay alone during the winter, while some had received an average of not over five pounds of barley in addition to their hay.

The cattle each year were in a half-fat condition, with not sufficient finish to sell satisfactorily, yet too good and too large to turn out on the range. The first two years the cattle were on pasture nearly four months, but the third year the cattle were sold at the end of the third month.

TABLE VI. GAINS ON PASTURE

(Three-year average)

Month	Number of steers	Weight at beginning	Weight at close	Monthly gain	Daily gain
		lbs.	lbs.	lbs.	lbs.
First	196	1184	1215	31	1.00
Second	196	1215	1288	73	2.39
Third	196	1288	1359	71	2.31
Fourth	148	1364	1379	15	0.70

The first month that the cattle were on pasture their average gain was one pound a day. The pasture was extra good and the cattle were not turned out until late in the season, but steers do not do so well when first turned on grass. The second and third months the gains were very good; the cattle put on a great deal of weight and finish. The fourth month was unsatisfactory, the pastures being dry and the weather hot. Due to the low gains made the fourth month during the first two years, the cattle were sold the third year before the pasture failed. Since the cattle were already in good marketable condition, however, and there was no advantage in holding them longer even if the pastures had been good, this failure of the pasture was not a drawback of any importance. The first year the steers sold in Portland for an average of 40 cents per 100 pounds over the quoted top. The second year we were offered the top price in Portland, but shipped the steers to Kansas City, where we sold them for $8.80, the top quotation for Western cattle on the day of sale. The third year they brought the quoted top in Seattle. Since these cattle were average Eastern Oregon feeder steers and not fancy in any way, it will be apparent that the finish obtained was very satisfactory.

This pasture was considered to have a value at this time of $1.00 a head a month, but this is an estimated value only. Due to a lack of uniform conditions and the spotted nature of the land, no figures that would be of any general application can be given as to its value or carrying capacity per acre. The quality of the pasture, however, may be considered as about the same as average blue-grass and mixed pasture throughout the Northwest. The use of such pasture for finishing steers for the midsummer market proved, on the whole, satisfactory and economical.

PART VI. FINANCIAL DISCUSSION

"Is there any money in feeding steers, and if so, how much?" This is a question which cannot be answered definitely, due to the fact that the answer is different for every farmer and for every season. We can give data, however, which will enable the feeder to estimate as accurately as is possible his probable profits or losses when feeding cattle under normal conditions. The exact profits or losses of the Experiment Station or of any feeder for any one particular feeding period form no criterion of what may be expected from feeding cattle year after year; conditions are rarely the same two years in succession. The information which is most useful and important to the feeder, therefore, is that which pertains to the amount of the various feeds required to fatten a steer, and the gains the steer will make under normal conditions. With this information at hand, knowing his feed cost, and with a reasonable knowledge of the market, the feeder is able to estimate with a fair degree of accuracy what he can do feeding cattle under his own conditions.

Hay Alone. In determining the cost of feeding steers on alfalfa hay alone, the following data, which are averages of five years' work, may be used as a basis for calculation.

Wt. at beginning	1000 lbs.
Wt. at close	1116 lbs.
Gain	.97 lb. per day, or 116 lbs. in 120 days
Hay offered	37 lbs. per day, or 4440 lbs. in 120 days
Hay refused	5 lbs. per day, or 600 lbs. in 120 days
Hay consumed	32 lbs. per day, or 3840 lbs. in 120 days

Table VII gives these figures in usable form.

TABLE VII: FATTENING ON HAY ALONE

	Price per 100 pounds at which the finished steer must be sold in order to pay for feed, interest, and labor		
	If feeder steers cost 5c a pound	If feeder steers cost 7c a pound	If feeder steers cost 9c a pound
With alfalfa at $ 5.00	$5.92	$7.76	$9.60
With alfalfa at $ 7.50	6.41	8.25	10.09
With alfalfa at $10.00	6.91	8.75	10.59
With alfalfa at $12.50	7.41	7.25	11.09
With alfalfa at $15.00	7.91	9.75	11.59

The costs given in this table include feed, interest on the cattle at 8 percent, and labor at the rate of $0.03 a steer per day. The labor cost is derived by allowing $4.50 a day for a man and team to feed one hundred fifty head of cattle. It will be noted that the figures given are not for the cost of the gain put on during the feeding period, but represent the final cost of the finished steer, or in other words, the price at which the steer must be sold in order to break even. For instance, a 1000-pound steer bought for $7.00 in the fall and fed 120 days on alfalfa at $10.00 a ton, must be sold for $8.75 in order just to cover the cost of hay, interest, and labor. Anything above $8.75 that he may bring will be clear profit. These prices are farm prices, and where the cattle are either bought or sold at other market points allowance must be made for transportation charges and shrinkage.

No allowance is made for the 600 pounds of refused hay, which, however, has a value for wintering stock cattle about half that of good hay.

The value of manure is also not included in this statement. Manure will usually amount to about three tons a steer.

These two items, namely, refused hay from the feed bunks and the manure, should be valued by the feeder according to his own local conditions.

The stockman who can and does make good use of the refused hay and manure has an advantage of several dollars a steer over the man who is unable to make use of these otherwise waste products.

Hay and Silage. As has already been shown, steers fed on hay and silage made 64 percent more gain than those fed on hay alone. The gains, too, are not only much greater but are more economical as well.

Market prices for silage are not well established, and the cost of production is exceedingly variable.

At this Station, where conditions are exceptionally favorable to growing cheap alfalfa while frost makes silage more expensive, the cost of one ton of silage is almost as much as the cost of one ton of hay; while on the other hand farm management surveys in Malheur county only show one ton of silage costing 40 percent as much as one ton of alfalfa. In this discussion we have rated the silage at 80 percent of the cost of one ton of alfalfa, but this is a purely arbitrary figure.

In calculating the cost of fattening steers on hay and silage the following data may be used as a basis.

Wt. at beginning		1000 lbs.
Wt. at close		1200 lbs.
Gain	1.67 lbs. per day, or	200 lbs. in 120 days
Hay offered	22.8 lbs. per day, or	2736 lbs. in 120 days
Hay refused	2.8 lbs. per day, or	336 lbs. in 120 days
Hay consumed	20 lbs. per day, or	2400 lbs. in 120 days
Silage	23.7 lbs. per day, or	2840 lbs. in 120 days

Table VIII further illustrates the importance of this ration of hay and silage in connection with the actual cost of fattening two-year-old steers.

TABLE VIII. FATTENING ON HAY AND SILAGE

	Price per 100 pounds at which the finished steer must be sold in order to pay for feed, interest, and labor		
	If feeder steers cost 5c a pound	If feeder steers cost 7c a pound	If feeder steers cost 9c a pound
With alfalfa @ $5.00 and silage @ $4.00	$5.62	$7.35	$9.04
With alfalfa @ $7.50 and silage @ $6.00	6.14	7.85	9.57
With alfalfa @ $10.00 and silage @ $8.00	6.66	8.38	10.09
With alfalfa @ $12.50 and silage @ $10.00	7.19	8.90	10.61
With alfalfa @ $15.00 and silage @ $12.00	7.71	9.42	11.14

The figures in Table VIII represent the actual costs in the feed yards and do not include any marketing expense. The cattle were weighed on a fill both at the beginning and at the close of the test. By comparing Table VIII with Table VII it will be observed that the final cost of silage-fed steers ranges from $0.20 to $0.56 per hundred less than the final cost of steers fed hay alone.

Many feeders measure their financial returns in terms of the price received for the feed. The following table, therefore, gives the probable returns for the feed under various conditions.

TABLE IX. NET PRICE RECEIVED FOR FEED IN THE STACK OR SILO

	Hay fed alone	Hay and silage*	
		Hay	Silage
If steers cost 5c and sell for 6c	$ 5.42	$ 6.85	$ 5.48
If steers cost 5c and sell for 7c	10.45	11.65	9.32
If steers cost 7c and sell for 8c	6.22	8.23	6.58
If steers cost 7c and sell for 9c	11.25	13.03	10.44

*In determining the relative prices received for the hay and silage the total received for the feed is divided on the basis of the silage being worth 80 percent as much per ton as the hay.

Since the gains made during the winter feeding period in all cases cost more than the market price of beef, it is therefore necessary to sell the finished steer at a higher price per hundred than he cost as a feeder. In other words, there must be a suitable margin between the cost and selling price in order to break even. We expect this higher price because the finished steer dresses out a larger percentage and the meat is of higher quality. The increase in price per hundred, or "margin," which we will actually get depends upon two factors: the finish of the steer and the fluctuations of the market. If the steer has gained slowly he may be no fatter than he was at the start, although heavier. On the other hand, if he has gained rapidly he will be much fatter and will demand a higher price. We usually expect a good steer that has gained two pounds a day for 120 days to be worth $1.00 to $1.50 per hundred more than he was worth in feeder condition, providing, of course, that the market has remained unchanged. A steer that has gained only one pound a day for 120 days will not be very fat and would probably bring only $0.50 to $0.75 more per hundred than he did as a feeder. This margin is usually greater when cattle prices are high than when prices are low.

The market seldom remains steady for any length of time but is constantly fluctuating. There is a common belief that fat cattle are much higher at the end of the winter than at the beginning, but this is often exaggerated. Through a long series of years there is little difference at Chicago between prices in November and December and prices in March and April. The Portland market on the average strengthens a little in the late winter, but there are many exceptions. There are years when even the best feeders lose money, and then again there are years when even the poorest feeders make some profit. In the long run, the ups and downs of the market very largely counterbalance each other.

The steer that has gained from 175 to 225 pounds during the winter feeding period and sells for $1.00 to $1.50 per hundred more than his cost price, should in general make the feeder some profit. When the costs of feed are such that the finished steer cannot be profitably sold for this margin, about the only chance for profit lies in a rise in the market, which is of course uncertain.

The fattening of steers is a good method of marketing hay and silage. The feeder should buy his cattle carefully, however, feed carefully, and utilize the waste hay and manure.

The dealer and trader often finds it profitable to maintain a feed yard in which he may place any thin cattle which can be bought cheap and from which he can take fat cattle whenever prices are right. Such a feed yard may show a handsome profit through the buying and selling ends, even though the actual gains put on may cost all they are worth.

Feeding cattle on a speculative basis where both feed and cattle are bought and fed under conditions such that neither the refused hay nor the manure can be utilized may show a profit during favorable seasons, but often shows a loss.

It is neither necessary nor desirable that the Northwest should winter-fatten more steers, but it is very important that the steers now being fed return greater profit. This can fortunately be obtained by the use of home-grown silage. The results tabulated in this bulletin conclusively show that by the use of silage along with alfalfa hay, very much larger and cheaper gains can be made than were possible under the old methods, and that the profits can be correspondingly increased.

PART VII. HINTS ON MANAGEMENT OF FATTENING STEERS

Buying Steers. In order to avoid excessive shipping charges steers should be bought as near the feed yard as possible; they commonly cost about as much in one place as another. While we do not buy fat cattle for feeding purposes, yet we want them in good flesh; the thinner they are, the longer it takes to finish them and the less we can afford to pay for them. A steer to be finished during 120 days of winter feeding should weigh about a thousand pounds at the beginning. The younger he is the better, providing he is up to weight. Dairy-bred stuff, high flanked, or rough unthrifty individuals should be avoided. If it is necessary to take such cattle with a bunch, they had better be sold to the local butcher at once for whatever they will bring, rather than keep them longer and invest good feed in them. Breed is immaterial so long as it is a beef breed.

Since we expect fat cattle to be worth more than feeders, it is of course necessary to buy feeders at around $1.00 per 100 pounds less than the current price of good beef. Many of the losses made in cattle feeding have been the result of paying fat-cattle prices for feeders.

Fall Pasture. There is often good pasture around the field and meadows in the fall that will produce good gains at much less cost than can be obtained in the feed yards. Fattening steers will cease to gain, however, long before the feed is entirely gone, and if the fields are to be well cleaned, the steers must be taken off before the feed gets short, stock cattle being turned in to clean up the remainder. If no stock cattle are available, it is better to waste some feed than to force the steers to eat it all, for they will shrink considerably in doing so.

Feeding Hay. Hay should be fed at least three times a day. Feed consumption is encouraged by frequent offerings of fresh hay. The refused hay should be cleaned out once a day, preferably while the steers are eating their silage. A large hay consumption is essential from the beginning and the hay must therefore be of good quality and carefully fed.

Feeding Silage. Silage is fed in bunks the same as grain. The cattle are fed at the rate of about 10 pounds a head the first day. Within two or three days this amount can be increased to 20 or 30 pounds as desired. There is very little danger of cattle going off feed on silage. A ration of 15 pounds may be fed all in one feed but with larger amounts it should be fed in two feeds, morning and evening.

Water and Shelter. Steers must have plenty of clean water where they can walk up and drink their fill at any time they wish without slipping on ice or wading in deep mud. Tank heaters to prevent ice are recommended. The feed yards should be well drained and sheltered as much as possible. The use of barns and also of warm water in connection with winter feeding have not so far proved profitable. (See Bulletin 183.)

Quiet and Regularity. Fattening steers must be handled as quietly and gently as possible, and any excitement which makes them leave their feed even for only a minute must be carefully avoided. An exact schedule should be worked out and carefully adhered to. Cattle appreciate having their meals on time as much as human beings. The feed yards should be provided with plenty of bedding and conditions in general should be made as comfortable as possible.

Season for Feeding. Winter feeding should begin early in the fall before the pasture begins to fail. The feeding should end when the cattle are fat, which is usually in from three to five months, depending largely upon the ration fed and the condition of the cattle at the beginning. Feeding should end, however, before spring weather comes, when cattle are inclined to become restless and consequently do not gain well. Cattle that have been on heavy feed during the winter should not be turned out on grass unless the pasture is extra good and even then not unless they are to stay there for at least two months. During the first month on spring pasture cattle do not make satisfactory gains, especially if already in fairly good condition.

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Oregon Agricultural College

Experiment Station

Oats and Vetch Versus Corn or Sunflowers for Silage

By

ROY C. JONES

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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Appendix 20

USE MORE OATS-AND-VETCH FOR SILAGE IN WESTERN OREGON

Oats-and-vetch, on the heavier, poorly drained soils, yields more tonnage than corn or sunflowers.

Oats-and-vetch silage produced slightly more milk than either corn or sunflowers in tests at the Oregon Experiment Station.

Oats-and-vetch fills the silo in early summer and keeps it from drying out and falling down.

Oats-and-vetch, placed in the silo in the spring and used out during the summer, allows double use of the silo, as it can be filled again in the fall with corn or sunflowers.

Oats-and-vetch is planted in the fall when other farm work is not so driving as in the spring.

Oats-and-vetch requires no cultivation after sowing.

Vetch is a legume and consequently a soil builder.

Oats and Vetch Versus Corn or Sunflowers for Silage

By

ROY C. JONES

Since the first silo was built and filled, many different crops, from maize to Russian thistles, have been ensiled with varying degrees of success. The common crops used in Western Oregon are corn, oats-and-vetch, and sunflowers. Many questions about the suitability of these crops for silage are constantly being received by this Experiment Station. The following are representative of the questions received. Which crop yields the most? Which produces the most milk? Does a silo full of oats-and-vetch weigh the same as a silo full of corn? Do the different kinds of silage have any effect on the flavor or quality of the butter-fat?

In order to have definite knowledge with which to answer these questions, this Station has conducted trials during the past three years involving thirty-six cows, or rather thirty-two different animals, as four of the animals were used two years in succession. The detailed plans and results are shown in the latter part of this bulletin.

RECOMMENDATIONS AND SUMMARY

Our recommendation for the practical application of these results is as follows: *Grow more oats-and-vetch for silage.*

Yields

On the dairy farms of Western Oregon, having heavy, rather poorly drained soil, oats- or barley-and-vetch should be grown much more extensively for silage purposes. It outyields corn about two to one. It nearly equals sunflowers in yield and far excels them in palatability. The average yields for the five years from 1918 to 1922 were: sunflowers 13.3 tons per acre, oats-and-vetch 9.6 tons, and corn 5.4 tons. The best yield of oats-and-vetch was 16.6 tons per acre, or more than any of the others. The Farm Crops department of the Station reports an average yield of oats-and-vetch from 1914 to 1921, on similar land, of 12.7 tons per acre.

Milk Produced

The oats-and-vetch silage produced a trifle more milk than the other kinds, the increase being about five percent. At the same time the cows gained .5 pound per day while getting the oats-and-vetch against .3 pound on corn and a bare maintenance of weight on the sunflowers.

Palatability

No difference could be noted between the oats-and-vetch and corn silage in the relish with which the cattle ate it. The sunflower silage, however, was so distasteful to most of the cows that they had to be partly starved before they would eat it and even then they did not relish it as much as the other silage. The Farm Crops department says that this can be overcome by the addition of 20 percent corn to the sunflowers when they are ensiled.

Grow Two Silage Crops

These facts do not necessarily mean that corn or sunflowers should not be grown as well as a crop of oats-and-vetch. There is quite an advantage in having a cultivated crop in the rotation. There is also an advantage in having a crop to put into the silo in the fall as well as in the spring. This gives one double use of the silo and enables one to get along with a smaller tonnage capacity.

Varieties to Grow

Common vetch and gray winter oats are the varieties which were used in the trials. These are the ones recommended by the Farm Crops department of the Station. The Farm Crops department also states that, for the Coast sections, purple vetch shows a little more promise than the common vetch, being easier to start and making an excellent growth. On the very heavy lands of the Willamette Valley, Hungarian vetch shows a great deal of promise. Winter barley can also be used with vetch for silage and produces good results.

Minnesota No. 13 was the variety of corn used, and Mammoth Russian was the variety of sunflowers.

Rate and Time of Seeding

Professor Hyslop states that the best results are obtained by using 60 to 80 pounds of vetch with 40 pounds of Gray winter oats per acre. The best time for sowing is usually from October 1 to 15. Well cultivated corn land can be made ready for vetch by simply disking and harrowing it.

Harvesting

Oats-and-vetch should be harvested for silage when the oats are in the light dough stage and the seeds are formed in the lower pods on the vetch. This is about the time it is usually cut for hay; it contains about 75 percent water at that time. If it is a little too mature, enough water should be added at the silo so that it will pack down well.

SILAGE INVESTIGATIONS

YIELDS

The Dairy Husbandry department grows annually about 20 acres each of corn and oats-and-vetch and for the past four years has grown from two to three acres of sunflowers. The yields shown in Table I are these actual farm yields and not small plot yields.

TABLE I. YIELDS IN TONS PER ACRE

	Oats-and-vetch	Sunflowers	Corn
1918	2.80*	....	4.6
1919	16.63	13.23	4.9
1920	16.00	15.00	5.5
1921	8.28*	15.00	5.0
1922	4.12†	10.00	7.2
Average	9.57	13.31	5.44

*A very severe infestation of aphis completely killed the vetch in 1918. In 1921 the early-sown vetch in two fields was badly damaged by a similar infestation, while one field, sown late after the removal of corn crop, was not damaged.

†Heavy frosts in February heaved the ground enough to kill most of the vetch.

The Farm Crops department reports an average yield of 12.7 tons of oats-and-vetch per acre for the years from 1914 to 1921. Corn yields check with ours quite closely. The Farm Crops department has not enough data on sunflowers to compare.

Over a period of five years, then, the sunflowers show the highest yield although in its good years the oats-and-vetch outyielded the sunflowers. The soil on which these crops were grown was rather poorly drained and very sticky, some of it classifying as white land and the rest very close to it.

WHICH PRODUCES THE MOST MILK?

The next question that naturally arises is, what are the comparative feeding values? In order to answer this question feeding trials have been conducted for the last three seasons, beginning 1919-20.

Trial 1, 1919-20

Plan. In the first year's trial the cows were not as carefully divided as in subsequent trials, so as to have the two groups uniform. The alternating method of feeding was used, however, so that the summary should not be seriously affected by this fact. The milk yield shown in Table II is that given in the first ten days in December. The trial started December 26.

TABLE II. DATA REGARDING COWS USED

Lot A				Lot B			
Herd No.	Breed	Fresh	10-day milk yield	Herd No.	Breed	Fresh	10-day milk yield
			lbs.				lbs.
404	Ayrshire	Aug. 4, 1919	241.0	421	Ayrshire	Sept. 17, 1919	234.6
407	Ayrshire	Aug. 23, 1919	330.3	424	Ayrshire	April 29, 1919	127.8
405	Ayrshire	Jan. 31, 1919	79.0	216	Holstein	Jan. 30, 1919	136.4
408	Ayrshire	July 3, 1919	270.7	217	Holstein	Jan. 28, 1919	245.6
414	Ayrshire	June 19, 1919	211.1	602	Guernsey	Mar. 24, 1919	135.0
418	Ayrshire	July 21, 1919	139.6	19	Jersey	April 14, 1919	163.9
Total			1271.7	Total			1063.3

The 12 cows selected as above were fed a basal ration consisting of ten pounds of clover hay, one pound of grain to every three pounds of milk produced per day, and all the silage they would consume. The grain mixture consisted of 200 pounds mill-run, 100 pounds dried beet pulp, 25 pounds cocoanut meal, and 15 pounds linseed oil meal. A preliminary period of 10 days was allowed on each feed in order to fill the animals on the feed in question, then feeding was continued for 30 more days and weights recorded and used in results. Periods 1, 5, and 9 were preliminary or transition periods.

Results. The milk and fat produced and feed consumed are shown in Tables III and IV for the two lots and summarized in Tables V and VI.

TABLE III. PRODUCTION AND FEED CONSUMPTION FOR LOT A, 1919-20

10-day periods	Milk	Fat	Hay	Grain	Oats-and-vetch silage	Sunflower silage	Corn silage
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs
2	1109.3	43.93	600	422.0	1750.5	....	....
3	1117.6	44.26	600	396.8	2052.5	....	....
4	1100.0	43.56	596	380.0	1991.5	....	....
Total	3326.9	131.75	1796	1198.8	5794.5	....	....
6	973.4	36.21	580	335	....	1402	....
7	955.4	35.54	580	335	....	1296	....
8	924.6	34.40	580	403	....	1292	....
Total	2853.4	106.15	1740	1073	....	3990	....
10	933.9	31.65	580	409	....	....	1333
11	893.4	30.29	586	405	....	....	1698
12	842.4	28.51	600	405	....	....	1881
Total	2669.7	90.45	1766	1219	....	....	4912

TABLE IV. PRODUCTION AND FEED CONSUMPTION FOR LOT B, 1919-20

10-day periods	Milk	Fat	Hay	Grain	Oats-and-vetch silage	Sunflower silage	Corn silage
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2	896.9	33.63	600	350	1682.5	....	....
3	930.0	34.88	598	314	2157.5	....	....
4	928.6	34.82	582	290	2166.0	....	....
Total	2755.5	103.33	1780	954	6006.0	....	....
6	930.8	37.41	580	290	....	....	1900
7	948.9	38.15	580	290	....	....	1900
8	942.1	37.87	580	290	....	....	1838
Total	2821.8	113.43	1740	870	....	....	5638
10	844.7	35.48	562	277	....	1795	....
11	833.2	34.99	572	275	....	1655	....
12	774.1	32.51	600	275	....	1645	....
Total	2452.0	102.98	1734	827	....	5095	....

TABLE V. SUMMARY LOTS A AND B, 1919-20

	Milk	Fat	Hay	Grain	Silage
	lbs.	lbs.	lbs.	lbs.	lbs.
Oats-and-vetch	2006.2	77.59	1200	772.0	3433.0
	2047.6	79.14	1198	710.8	4210.0
	2028.6	78.38	1178	670.0	4157.5
Total	6082.4	235.11	3576	2152.8	11790.5
Corn	1864.7	69.06	1160	699	3233
	1842.3	68.44	1166	695	3598
	1784.5	66.38	1180	695	3719
Total	5491.5	203.88	3506	2089	10550
Sunflower	1818.1	71.69	1142	612	3197
	1788.6	70.53	1152	610	2951
	1698.7	66.91	1180	678	2937
Total	5305.4	209.13	3474	1900	9085

TABLE VI. SUMMARY LOTS A AND B, 1919-20, FEED CONSUMED PER UNIT OF PRODUCT

	—Per 100 pounds milk—			—Per pound fat—		
	Clover hay	Grain	Silage	Clover hay	Grain	Silage
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Oats-and-vetch	58.8	35.4	193.8	15.2	9.15	50.1
Corn	63.8	38.0	192.8	17.2	10.20	51.7
Sunflowers	65.5	35.8	171.2	16.6	9.10	43.4

These tables show that in actual yield of milk the oats-and-vetch silage ranks first, corn second, and sunflowers third.

Considerable difficulty was experienced in getting the cows to consume the sunflower silage readily. It did not seem to be as palatable as the other kinds. Some cows seemed to take a greater dislike to it than others. They did not consume enough of the sunflower silage to maintain their body weight, the 12 cows losing 186 pounds during the 30 days. On oats-and-vetch they gained 345 pounds and on corn 191 pounds.

Trial 2, 1920-21

Plan. A second test was started in February, 1921. More care was taken to equalize the two groups of cows as regards breed, freshening date, and milk yield, as will be seen from Table VII.

TABLE VII. DATA REGARDING COWS USED, 1920-21

Cow	Breed	Fresh	Milk in Jan. 1921
		Group A	
			lbs.
22	Jersey	Nov. 21, 1920	785.6
212	Holstein	Oct. 29, 1920	1898.9
221	Holstein	Nov. 3, 1920	679.2
415	Ayrshire	Nov. 8, 1920	928.1
421	Ayrshire	Oct. 29, 1920	1129.2
425	Ayrshire	Jan. 5, 1921	880.0 (est.)
			6301.0
		Group B	
			lbs.
612	Guernsey	Nov. 15, 1920	712.9
213	Holstein	Dec. 5, 1920	1417.4
222	Holstein	Nov. 30, 1920	1143.2
423	Ayrshire	Oct. 10, 1920	888.5
426	Ayrshire	Oct. 13, 1920	1228.0
431	Ayrshire	Nov. 16, 1920	927.7
			6317.7
436*	Ayrshire	Jan. 16, 1921	806.0 (est.)

*Substituted for 431 on account of sickness.

Grain was fed as in the previous trial, but alfalfa hay was fed in place of the clover, which was not available. The hay was fed at the rate of 1 pound for each 100 pounds of weight in the cow. Silage was fed at 3 pounds per 100 pounds of body weight.

The A group was started on oats-and-vetch silage, while the B group received sunflower silage.

Results. The same lack of palatability of the sunflower silage appeared as in the previous year; in fact, cow 431 went completely off feed during her preliminary period, and 436 was added to the group, making 7 cows in Group B. Subsequent experience with 431 has shown her to be extremely fastidious in her appetite even when sunflowers are not concerned, so we have eliminated her from the tables in this trial.

Tables VIII, IX, X, and XI show the results of this trial using six animals in each group and eliminating cow 431.

TABLE VIII. LOT A, 1920-21

10-day periods	Milk	Fat	Hay	Grain	Oat-and-vetch silage	Sunflower silage	Corn silage
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2	1834.7	24.31	650	565	1890	....	....
3	1756.5	71.14	650	565	1891	....	....
4	1733.3	70.20	650	565	1900	....	....
Total	5324.5	215.65	1950	1695	5681	....	....
6	1714.6	66.36	650	565	....	....	1900.0
7	1680.6	65.04	650	565	....	....	1891.5
8	1609.6	62.29	643	565	....	....	1838.0
Total	5004.8	193.69	1943	1695	....	....	5629.5
10	1535.5	61.42	650	565	....	1842	....
11	1527.7	61.11	650	565	....	1900	....
12	1628.7	65.15	650	565	....	1900	....
Total	4691.7	187.68	1950	1695	....	5642	....

TABLE IX. LOT B, 1920-21

10-day periods	Milk	Fat	Hay	Grain	Oat-and-vetch silage	Sunflower silage	Corn silage
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2	1616.4	61.75	620	575	....	1810	....
3	1650.5	63.05	620	575	....	1820	....
4	1614.9	61.69	620	575	....	1820	....
Total	4881.8	186.49	1860	1725	....	5450	....
6	1481.0	60.87	620	575	1806.7	....	....
7	1301.4	53.49	618	575	1804.5		....
8	1371.4	56.36	615	575	1820.0	....	....
Total	4153.8	170.72	1853	1725	5431.2	....	....
10	1313.0	50.29	620	575	....	....	1820
11	1356.2	51.94	620	575	....	....	1820
12	1412.7	54.11	620	575	....	....	1820
Total	4081.9	156.34	1860	1725	....	....	5460

TABLE X. SUMMARY LOTS A AND B, 1920-21

	Milk	Fat	Hay	Grain	Silage
	lbs.	lbs.	lbs.	lbs.	lbs.
Oats-and-vetch	3315.0	135.18	1270	1140	3696.7
	3057.9	124.63	1268	1140	3695.5
	3104.7	126.56	1265	1140	3720.0
Total	9477.6	386.37	3803	3420	11112.2
Corn	3027.6	116.65	1270	1140	3720.0
	3036.8	116.95	1270	1140	3711.5
	3022.3	116.40	1270	1140	3658.0
Total	9086.7	350.00	3810	3420	11089.5
Sunflower	3151.9	123.17	1270	1140	3652
	3178.2	124.16	1270	1140	3720
	3243.6	126.84	1270	1140	3720
Total	9573.7	374.17	3810	3420	11092

TABLE XI. FEED CONSUMED PER UNIT OF PRODUCT

	Per 100 pounds milk			Per 1 pound fat		
	Hay	Grain	Silage	Hay	Grain	Silage
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Oats-and-vetch	40.1	36.1	117.2	9.8	8.8	28.8
Corn	41.9	37.6	122.0	10.9	9.8	31.7
Sunflowers	39.8	35.7	115.8	10.2	9.1	29.7

In amount of milk produced during this trial the sunflower silage ranks first, oats-and-vetch second, and corn last. With the exception of cow 431, these cows exhibited little difficulty with the sunflower silage although they did not take it as readily as they did the other kinds. The 12 cows gained 149 pounds in the 30 days on sunflowers, 129 pounds on oats-and-vetch, and 25 pounds on corn.

Trial 3, 1921-22

Plan. The general plan followed was the same as in Trial 2. Clover hay was again available and was used instead of alfalfa. Lot A was fed oats-and-vetch silage during period 1, followed by sunflower and then corn. Lot B was started with corn, followed by oats-and-vetch and sunflowers. We had the misfortune to lose cow 429 in lot B just as she started her final period due to the effects of a piece of baling wire she had swallowed. In order to equalize the groups we therefore eliminated from the tables her record and the record of cow 431, the animal she was paired with, making 10 cows in the trial.

TABLE XII. DATA REGARDING COWS USED

Lot A				Lot B			
Cow	Breed	Fresh	Dec. milk	Cow	Breed	Fresh	Dec.milk
			lbs.				lbs.
22	Jersey	Dec. 7, 1921	878*	23	Jersey	Dec. 29, 1921	*806
227	Holstein	June 8, 1921	552	224	Holstein	July 6, 1921	563
405	Ayrshire	Aug. 17, 1921	789	408	Ayrshire	Sept. 29, 1921	826
431	Ayrshire	Dec. 5, 1921	900*	429	Ayrshire	Dec. 16, 1921	*900
432	Ayrshire	Sept. 24, 1921	738	420	Ayrshire	Sept. 21, 1921	826
441	Ayrshire	Nov. 9, 1921	580	442	Ayrshire	Dec. 8, 1921	750
Total			4437				4435

*Estimated to full month.

Results. Tables XIII to XVI show the results of this trial after eliminating cows 429 and 431.

TABLE XIII. LOT A, 1921-22

10-day period	Milk	Fat	Hay	Grain	Oats-and-vetch silage	Sunflower silage	Corn silage
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
2	1039.8	46.79	480	350	1420	....	....
3	981.3	44.16	480	350	1420	....	....
4	933.5	420.10	480	350	1420	....	....
Total	2954.6	132.96	1440	1050	4260	....	....
6	800.3	37.61	480	350	....	1345	....
7	812.8	38.20	480	350	....	1298	....
8	878.2	41.28	480	350	....	1298	....
Total	2491.3	117.09	1440	1050	....	3941	....
10	723.2	34.14	480	350	....	....	1420
11	769.0	36.30	480	350	....	....	1420
12	857.1	40.45	480	350	....	....	1420
Total	2349.3	110.89	1440	1050	....	....	4260

TABLE XIV. LOT B

10-day period	Milk	Fat	Hay	Grain	Oats-and-vetch silage	Sunflower silage	Corn silage
	lbs.	lbs.	lbs	lbs.	lbs.	lbs.	lbs.
2	1058.0	46.34	490	370	....	....	1360
3	1013.9	44.41	490	370	....	....	1360
4	983.4	43.07	490	370	....	....	1360
Total	3055.3	133.82	1470	1110	....	....	4080
6	863.0	34.16	490	370	1360	....	....
7	848.6	33.60	490	370	1360	....	....
8	830.9	32.90	490	370	1360	....	....
Total	2542.5	100.66	1470	1110	4080	....	....
10	764.2	31.94	490	370	....	1256	....
11	762.9	31.89	490	370	....	1291	....
12	793.5	33.17	490	370	....	1356	....
Total	2320.6	97.00	1470	1110	....	3903	....

TABLE XV. SUMMARY LOTS A AND B, 1921-22

	Milk	Fat	Hay	Grain	Silage
	lbs.	lbs.	lbs.	lbs.	lbs.
Oats-and-vetch	1902.8	80.95	970	720	2780
	1829.9	77.76	970	720	2780
	1764.4	74.91	970	720	2780
Total	5497.1	233.62	2910	2160	8340
Corn	1781.2	80.48	970	720	2780
	1782.9	80.71	970	720	2780
	1840.5	83.52	970	720	2780
Total	5404.6	244.71	2910	2160	8340
Sunflowers	1564.5	69.55	970	720	2601
	1575.7	70.09	970	720	2589
	1671.7	74.45	970	720	2654
Total	4811.7	214.09	2910	2160	7844

TABLE XVI. FEED CONSUMED PER UNIT OF PRODUCT

	Per 100 pounds milk			Per 1 pound fat		
	Hay	Grain	Silage	Hay	Grain	Silage
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Oats-and-vetch	52.9	39.4	151.7	12.5	9.3	35.7
Corn	53.8	40.0	154.3	11.9	8.8	34.1
Sunflowers	60.4	44.8	165.1	13.5	10.1	36.6

Here the oats-and-vetch leads in amount of milk produced, with corn and sunflowers following in order. Again the sunflowers showed lack of palatability, but with a little coaxing the cows consumed quite liberal quantities. Cow 431 was much worse affected than the rest, but as she was paired with the heifer that died her figures were eliminated from the average. They are given later under the heading, Palatability.

Summary of Three Trials

Table XVII shows a summary of the milk produced, feed consumed, and gains or losses sustained during the three trials.

TABLE XVII. SILAGE EXPERIMENT SUMMARY: TOTAL MILK AND FEED THREE SEASONS

	Milk	Fat	Fat	Hay	Grain	Silage	Initial weight	Final weight	Gain	No. of cows
	lbs.	%	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
Oats-and-vetch										
1920	6082.4	3.86	235.11	3576	2152.8	11790.5	11799	12144	345	12
1921	9477.6	4.07	386.37	3803	3420.0	11112.2	11440	11569	129	12
1922	5497.1	4.25	233.62	2910	2160.0	8340.0	9515	9553	380	10
Total	21057.1	4.06	855.10	10289	7732.8	31242.7	32754	33266	512	34
Corn										
1920	5491.5	3.71	203.88	3506	2089	10550	12180	12371	191	12
1921	9086.7	3.85	350.00	3810	3420	11089.5	11454	11479	25	12
1922	5404.6	4.53	244.71	2910	2160	8340	9536	9619	83	10
Total	19982.8	4.00	798.59	10326	7669	29979.5	33170	33469	299	34
Sunflower										
1920	5305.4	3.94	209.13	3474	1900	9085	12208	12022	186*	12
1921	9573.7	3.91	374.17	3810	3420	11092	11385	11534	149	12
1922	4811.7	4.44	214.09	2910	2160	7844	9415	9500	85	10
Total	19690.8	4.05	789.39	10194	7480	28021	33008	33056	48	34

*Loss.

In this summary we still see the oats-and-vetch producing the largest amount of milk, with corn and sunflowers following in order. Giving the milk production on corn a rating of 100, the oats-and-vetch yielded 105.3, while the sunflowers yielded 98. In fat production, with corn as 100 again, the oats-and-vetch yielded 107, while the sunflowers went 100.

Table XVIII shows the same data worked down to a per-cow per-day basis. It will be noted that gains were made on both the oats-and-vetch and corn groups, while the sunflower group barely maintained themselves.

TABLE XVIII. AVERAGE PER COW PER DAY

	Milk	Fat	Fat	Hay	Grain	Silage	Gain
	lbs.	%	lbs.	lbs.	lbs.	lbs.	lbs.
Oats-and-vetch	20.64	4.06	.838	10.08	7.58	30.63	.5
Corn	19.59	4.00	.783	10.12	7.52	29.39	.29
Sunflower	19.30	4.05	.783	9.99	7.33	27.47	.05

Table XIX shows the digestible nutrients consumed in each feed each year and the pounds of total digestible nutrients and protein required for each hundred of milk and pound of fat.

TABLE XIX. DIGESTIBLE NUTRIENTS CONSUMED, POUNDS

			Protein	CH and fat	Protein per 100 pounds milk	Digestible nutrients per 100 pounds milk	Digestible nutrients per 1 pound fat
			lbs.	lbs.	lbs.	lbs.	lbs.
Oats-and-vetch	1920	Hay, clover	195.61	1649.61	....	....	....
		Grain	195.90	1267.92	....	....	....
		Silage	194.54	1575.21	....	....	....
		Total	586.05	4492.74	9.63	83.49	21.60
	1921	Hay, alfalfa	403.12	1559.23	....	....	....
		Grain	311.22	2012.67	....	....	....
		Silage	178.91	1713.50	....	....	....
		Total	893.25	5285.40	9.42	65.20	16.00
	1922	Hay, clover	221.16	1260.03	....	....	....
		Grain	196.56	1271.16	....	....	....
		Silage	130.94	1457.83	....	....	....
		Total	548.66	3989.02	9.98	82.55	19.42
		Grand total and average	2027.96	13767.16	9.63	75.01	18.47
Corn	1920	Hay, clover	191.78	1617.32	....	....	....
		Grain	190.10	1227.38	....	....	....
		Silage	142.43	1809.38	....	....	....
		Total	524.31	4654.03	9.62	94.37	25.40
	1921	Hay, alfalfa	403.86	1562.10	....	....	....
		Grain	311.22	2012.67	....	....	....
		Silage	128.64	1861.01	....	....	....
		Total	843.72	5435.78	9.28	69.10	17.94
	1922	Hay, clover	221.16	1260.03	....	....	....
		Grain	196.56	1271.16	....	....	....
		Silage	80.06	1217.62	....	....	....
		Total	497.78	3748.81	9.21	78.57	17.35
		Grand total and average	1865.81	13838.62	9.34	78.59	19.66
Sunflower	1920	Hay, clover	190.03	1602.56	....	....	....
		Grain	172.90	1116.15	....	....	....
		Silage	99.94	1097.47	....	....	....
		Total	462.87	3816.18	8.72	80.65	20.46
	1921	Hay, alfalfa	403.86	1562.10	....	....	....
		Grain	311.22	2012.67	....	....	....
		Silage	112.03	1228.99	....	....	....
		Total	827.11	4803.76	8.64	58.82	15.05
	1922	Hay, clover	221.16	1260.03	....	....	....
		Grain	196.56	1271.16	....	....	....
		Silage	72.16	791.08	....	....	....
		Total	489.88	3322.27	10.18	79.22	17.81
		Grand total and average 3 years	1779.86	11942.21	9.03	69.67	17.18

This table was calculated from our own analyses of the feeds, using the digestion coefficients given in Henry and Morrison's Feeds and Feeding.

When considered from this standpoint the sunflowers rank first, with oats-and-vetch second, and corn third, in total digestible nutrients required to produce 100 pounds of milk or 1 pound of fat. The difference is not great, however, and when we recall that on oats-and-vetch and corn the cattle gained we can only reach the conclusion that for milk production they are practically equal.

TABLE XX. SUMMARY OF TABLE XIX

Feed	Protein per 100 pounds milk	TDN per 100 pounds milk	TDN per 1 pound fat
Sunflowers	9.03	69.67	17.18
Oats-and-vetch	9.63	75.01	18.47
Corn	9.34	78.59	19.66

In the three trials 37 animals were started, comprising 32 individuals. One was lost by death and one eliminated for other reasons, making 30 different individuals included in averages. This should be enough to eliminate individual errors.

PALATABILITY

The lack of palatability of sunflower silage has been mentioned several times. This was much more noticeable with some individuals than with others, but it was noticed with nearly every cow under observation. Any of the cows could be changed abruptly from corn to oats-and-vetch silage or vice versa without apparent ill effect or loss of appetite. An abrupt change from either corn or oats-and-vetch to sunflower silage resulted in refusal to eat in all but one case.

The ten-day transition period was none too long to get the animals on to a full feed of the sunflower silage. With the exception of cows 432 and 442, none of the cows cleaned up the sunflower as ravenously as they did the other kinds. They would nose it around for some time before they would clean it up.

The appetite of cow 431 was affected the worst by the sunflower silage as it knocked her completely off feed both years she was used. Subsequent observation has shown her to be especially fastidious in her appetite whether sunflowers are concerned or not, but most of the cows showed their dislike for the sunflowers to a greater or less extent.

The accompanying graphs, Figs. 1 and 2, show the daily production of cow 431. Before being placed on experiment in 1920 (Fig. 1), she was receiving oats-and-vetch silage, alfalfa hay, and our regular herd mixture of grain. She was producing nearly 33 pounds of milk per day. In five days after starting sunflower feeding she was down to 21 pounds of milk per day. From this she recovered gradually back to nearly 27 pounds of milk, then took another tumble to less than 14 pounds fourteen days after starting the test. She refused not only her silage, but her grain as well. She finally became hungry enough to eat her rations and averaged 20.7 pounds per day for the sunflower period.

In her transition period from sunflowers to oats-and-vetch she averaged 22.2 pounds of milk, while for the next thirty days, on oats-and-vetch, she made 23.7 pounds of milk per day. The next forty days, on corn silage, she averaged 24.6 pounds per day, showing still further recovery.

Fig. 2 shows the corresponding facts for 1921-22, only she started on oats-and-vetch, tumbled when changed to sunflowers, and recovered again on corn.

Professor G. R. Hyslop, of the Farm Crops department of the Experiment Station, states that his experiments show this lack of palatability to be due to lack of the proper fermentation and that it can be overcome by adding a small amount of corn, twenty to twenty-five percent, to the sunflowers when they are put into the silo. We have not tried this in our Dairy Investigations as yet.

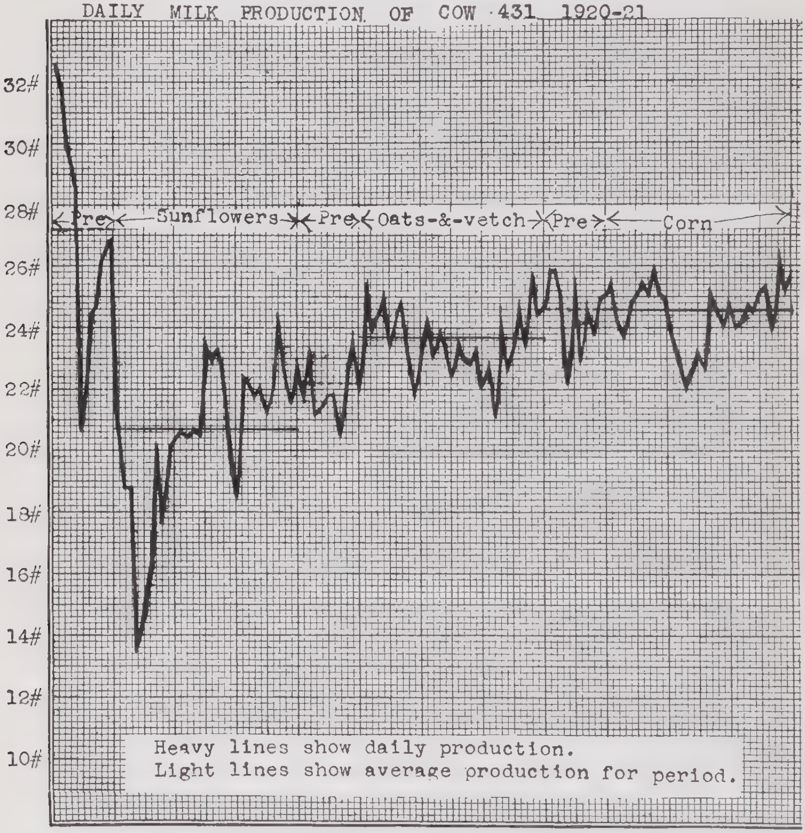

Fig. 1.

The seeds of the sunflowers were in the milk when they were cut.

THE EFFECT OF DIFFERENT KINDS OF SILAGE ON THE COMPOSITIONS AND CONSTANTS OF BUTTER-FAT

In order to determine if the various kinds of silage produced feed flavors or changed the properties of the butter-fat in any way, two days' milk was saved from each group after it had been on each kind of silage for 30 days. This milk was separated and the cream churned into butter. The butter was packed in crocks scoring for flavor when two days old, and during the last two trials was scored again when three weeks old. The following table shows the results of the scoring.

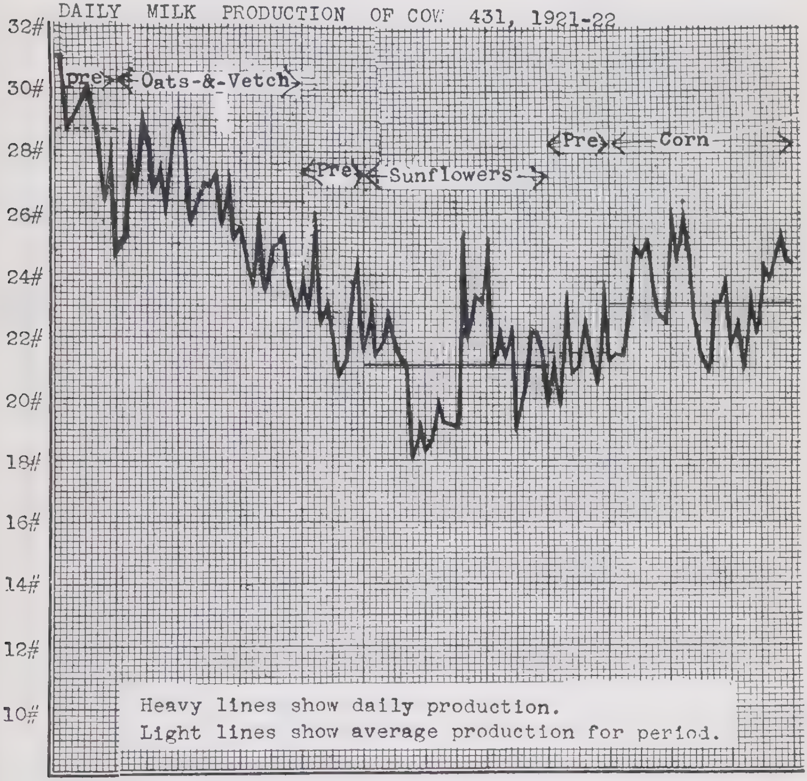

Fig. 2.

TABLE XXI. FLAVOR SCORES OF BUTTER

		1920			1921			1922		
		Criticism	Score on flavor	Same at 3 weeks	Criticism	Score on flavor	Same at 3 weeks	Criticism	Score on flavor	Same at 3 weeks
Oats-and-vetch	A	Rancid putrid	34	....	Rancid 2d score	36½	34		37	35
Oats-and-vetch	B	Combined with A	....	....		36	34½		36	35
Corn	A	Rancid	35	....		38	38		36	34
Corn	B	Slightly rancid	35	....		41	38	Slightly stale	36	35
Sun-flowers	A	Unclean, foreign	36	....		41	39	Tallowy	36	33
Sun-flowers	B	Musty, old cream	36	....	Tallowy rancid	36	31	Slight feed	35	34

Very little, if any, difference could be detected in the flavors of the two samples of butter made at the same time. A slight feed flavor was noticed in one of the samples from sunflower silage, but that is the only time that criticism appears. It is safe to say that no feed flavors were noticeable to any extent.

Samples of this butter were sent to the Experiment Station Chemist for determination of the constants of the butter-fat. Table XXII shows the results of these determinations.

TABLE XXII. *SUMMARY OF CHEMICAL RESULTS

Kind of silage Year	Kind	Hanus method iodine No.	Sapon. No.	Reichart Meissl No.	Melting point, centigrade	Ref. index
1920	Corn	31.220	230.400	27.87	32.275°	....
1921	Corn	29.640	230.950	28.295	31.925°	....
1922	Corn	20.035	225.500	26.205	32.000°	1.45435
		80.895	686.850	82.370	96.200°	....
Average		26.965	228.950	27.457	32.067°	....
1920	Sunflower	33.200	228.400	27.06	32.125°	....
1921	Sunflower	33.400	231.875	29.04	31.850°	....
1922	Sunflower	21.350	224.000	25.775	32.035°	1.45485
		87.950	684.275	81.875	96.010°	....
Average		29.317	228.092	27.292	32.003°	....
1920	Oats-and-vetch	29.950	230.000	27.10	32.400°	....
1921	Oats-and-vetch	30.360	235.000	29.85	31.230°	....
1922	Oats-and-vetch	18.430	228.250	27.59	32.985°	1.4539
		78.740	693.250	84.54	96.615°	
Average		26.247	231.083	28.18	32.205°	....

*Credit for the chemical work is due to Professor J. S. Jones, Experiment Station Chemist.

The only marked difference brought out by this table is in the iodine number, which shows the butter-fat from sunflower silage always higher than that from the other kinds. The average of all analyses shows the sunflower fat to have an iodine number of 29.317, corn 26.965, and oats-

and-vetch 26.247. This would indicate a larger content of olein in the sunflower butter-fat.

The 1922 determinations were all exceedingly low in iodine number as compared with the others. We cannot account for this, but their relation to each other seems to hold about the same as in other years.

As a basis for comparison the constants from nine samples of butter from all over the state as run by the Agricultural Chemistry department show the following average: Iodine No. 31.64, Saponification 228.7, Reichert Meissl No. 28.63, Melting Point 32.78°C.

MISCELLANEOUS FINDINGS

An apparatus similar to that worked out by the Kansas Station was obtained for taking a cubic foot of silage from the silo. It was planned to take the weights of a cubic foot of silage at two-foot intervals the entire depth of the silos. Through misunderstanding these weights were not all taken, but enough were taken to be of some value.

TABLE XXIII. WEIGHT PER CUBIC FOOT OF SILAGE, 1921

Kokeel (oats-and-vetch)				Concrete (corn)			
Height in silo	Weight per cu.ft.	Dry matter	Date	Height in silo	Weight per cu.ft	Dry matter	Date
ft.	lbs.	%		ft.	lbs.	%	
18	39	25.35	11- 6-20	18	48.0	22.1	2-14-21
13	41.5	28.60	11-30-20	16	50.0	23.63	2-26-21
10	40	28.95	12-18-20	14	50.0	23.40	4- 1-21
8	41	....	12-27-20	8	53.5	21.16	4-30-21
6	45	27.66	1- 6-21	6	53.0	....	5-12-21
4	45.5	28.20	2-20-21	2	59.0	....	6-15-21
2	44.8	28.62	5-20-21		......	....	
Average	42.4	27.9			52.3	22.57	

Filled to height of 38 ft., 4 in., settled to 31 feet — Filled to height of 33 feet, settled to 28 feet

Two men were tramping all the time while filling these silos.

TABLE XXIV. WEIGHT PER CUBIC FOOT SILAGE, 1922

Kokeel (oats-and-vetch)				Concrete (corn)				Stave (sunflowers			
Ht.	Wt.	DM	Date	Ht.	Wt.	DM	Date	Ht.	Wt.	DM	Date
ft.	lbs.			ft.	lbs.			ft.	lbs.		
34	31.5	....	7-20-21								
30	35	27.84	8- 3-21								
28	37.5	....	8-16-21								
26	37.5	....	8-31-21								
24	38	....	9- 9-21								
22	38	....	9-20-21								
20	41.5	....	10- 2-21								
18	44	26.85	10-15-21								
16	45	28	11- 3-21								
14	45.5	28.28	11-17-21								
12	45	30.06	11-29-21								
10	51.5	33.23	12-13-21	10	53	20.75	3-29-22				
8	50	29.52	12-28-21	8	50	22.93	4-25-22	8	46	18.05	3-29-22
6	51	31.87	1-12-22					6	49	19.65	4-25-22
4	51	31.75	2-15-22	4	53	26.16	5- 5-22	4	53	20.28	5-5-22
2	51	31.66	3- 2-22	2	50	24.65	5-29-22	2	55	18.01	5-29-22
Avg.	43.3	29.91			51.5	23.62			50.7	19.00	

Filled to 38 feet, settled to 34 feet. Automatic packer used on first half.

Filled to 34 feet
Settled to 29 feet
Two men tramping

Filled to 10 feet with sunflowers and then up to 15 feet with corn. Two men tramping.

Through misunderstanding samples were not taken in concrete and stave silos until nearly empty. It is interesting to compare the weights of oats-and-vetch in the Kokeel silo with the year before, when it was tramped. The average weight in the lower half after machine packing was 48.8 pounds, while after tramping with men it was only 42.4 pounds.

The packer used in the Kokeel silo did very good work when it could be made to run. It gave a great deal of trouble in this respect, however, and was finally dismantled and thrown out when the silo was about half full. It cost too much to hold a crew idle while the packer was being repaired.

CONCLUSIONS

1. Sunflower silage lacks in palatability.

2. There is very little difference in feeding value of the three kinds of silage as measured by milk yield.

3. The sunflower has yielded the largest tonnage per acre over a series of years, with the oats-and-vetch second, and the corn third.

4. During the years with a favorable season the oats-and-vetch yielded the highest tonnage.

5. Determination of chemical and physical constants of butter-fat indicates a slightly higher olein content of sunflower butter.

6. A cubic foot of oats-and-vetch silage weighs about four-fifths that of corn or sunflower silage.

7. The automatic packer increased the capacity of the silo 15.1 percent, but is not perfected sufficiently to be practical.

APPENDIX

ANALYSES OF SILAGE USED

Feed	Water	D.M.	Ash	C. Pro.	C. Fibre	N. F. E.	Ether extract
	%	%	%	%	%	%	%
Oats-and-vetch, 1920	76.87	23.13	1.64	2.20	7.99	10.62	.68
Oats-and-vetch, 1922	70.29	29.71	2.20	2.09	9.70	15.20	.52
Average	73.58	26.42	1.92	2.15	8.85	12.91	.60
Corn, 1920	73.00	27.00	1.39	2.64	4.45	17.55	.97
Corn, 1922	76.38	23.62	1.30	1.89	6.08	13.93	.42
Average	74.69	25.31	1.35	2.27	5.27	15.74	.70
Sunflower, 1920	77.62	22.38	1.55	2.24	6.22	11.52	.85
Sunflower, 1922	81.34	18.66	2.15	1.87	5.58	7.71	1.35
Average	79.48	20.52	1.85	2.06	5.90	9.64	1.10

Station Bulletin 195 December, 1922

Oregon Agricultural College

Experiment Station

Stump Land Reclamation in Oregon

By

H. D. SCUDDER

THE BIG STUMP IS THE PROBLEM

CORVALLIS, OREGON

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OREGON MUST LOOK AHEAD

Hundreds of thousands of acres of good but profitless stump lands in our state already await reclamation for agriculture.

Twenty-one million acres of standing timber remain, and we are just entering the great cutting era.

What shall we do? How can we begin replacing this huge wealth resource before it is exhausted and leaves us impoverished?

Can the best of this stump land be changed to profitable farms and thus bring enduring wealth to Oregon?

This is one of our most difficult problems in land economics, and as yet it is a problem unsolved.

Can we produce a convincing, practical, commercially successful solution to this problem, that will bring genuine aid and guidance to the settler on the stump lands, or must we wait for slow and costly natural economic evolution to work this problem out for us at the expense of generations of settlers?

This bulletin describes a new method of land clearing to which the Oregon Experiment Station has given years of study and on which it has reached conviction.

It is a simple, logical, practical method. It cuts the cost of clearing big stump land in two.

What shall we do with it. Can we establish it?

Simple and practical as it is, yet it is new. Many at first will fail to use it correctly and successfully. It will take effort and patience and persistence to put it in use. New methods in agriculture, no matter how sound and good, take years to become established.

County agricultural agents and College Extension Service can do much. Owners of timber and logged-off land, bankers, chambers of commerce, and development bodies can do more. Put this method to the commercial test, and in a few years we may have it permanently established and in use.

Stump Land Reclamation in Oregon

A New Method of Clearing the Big Stump Land

By

H. D. SCUDDER

THE STUMP LAND PROBLEM

FOREWORD

Free lands for new homesteads in the West are gone. While there are millions of acres of public land and grant land still untaken, there remain few claims of sufficient value to justify their cost in money, time, labor, and social and economic isolation.

The seeker after new land must turn in future largely to those areas still unreclaimed from desert, swamp, and forest. In these lie our richest remaining land resources. With the advance of settlement in search for further agricultural domain, the reclamation of these lands has assumed a commanding position in land economics.

Reclamation of our arid and swamp lands through irrigation and drainage has progressed to successful establishment in fact as well as in public confidence. Reclamation of stump land, in an organized way, has hardly been touched upon. Yet here lies our greatest remaining field for reclamation work. The extent and importance of this field has not been realized by the general public. Further and more careful exploration of its possibilities must perhaps precede any extensive reclamation of this land. A brief comparison, however, is indicative both of the great future interest we may come to take in this land resource and of the magnitude of the problem it presents.

CLASSES OF RECLAIMABLE LAND IN UNITED STATES

Estimated total area of irrigable land in United States	15,000,000 acres.*
Estimated total area of swamp and overflow land in United States	80,000,000 acres.*
Estimated total area of stump land in United States	240,000,000 acres.†

DISTRIBUTION OF CHIEF AREAS OF CUT-OVER LANDS, UNITED STATES
(Annual Report, Secretary of the Interior, 1918.)

State	Acres	State	Acres
Maine	6,135,000	Alabama	14,785,000
New Hampshire	2,608,000	Mississippi	13,203,000
Vermont	2,070,000	Louisiana	11,877,000
New York	5,997,000	Texas	12,936,000
Pennsylvania	5,297,000	Arkansas	13,893,000
New Jersey	1,151,000	Missouri	8,900,000
Maryland	1,848,000	Michigan	11,686,000
West Virginia	4,634,000	Wisconsin	13,246,000
Virginia	9,929,000	Minnesota	14,022,000
Kentucky	3,222,000	Montana	674,000
Tennessee	7,833,000	Idaho	676,000
North Carolina	12,745,000	Washington	3,330,000
South Carolina	8,994,000	Oregon	3,537,000
Georgia	20,141,000	California	3,031,000
Florida	10,109,000		
(Minor areas omitted)		Total	228,509,000

*Estimates of U. S. Department of the Interior. †U. S. Forest Service.

Of these vast areas, the portion valuable for agriculture and worth reclaiming has not as yet been determined. A primary step in national land economics, that it is none too early to take, is an inventory and classification of these lands as to their value and best utilization. While it is true that a large portion of the cut-over land is more valuable for reforestation than for agriculture, it is likewise true that an enormous area of potential farm land now in stumps, far in excess of any other class of reclaimable land, awaits practicable agencies for reclamation.

STUMP LAND PROBLEM IN PACIFIC COAST STATES

In Oregon, the Northwest and Pacific Coast states generally, the stump-land problem, though already of great interest and importance in many localities, is as yet in its early stages. Statements in a recent publication* on our forest resources make this clear. "The great pine forests of New England and the Lake states are practically cut out. * * * The New England region now ships in about thirty percent of the lumber it consumes. The Lake states region * * * consumes the equivalent of 70 percent of the total it cuts, leaving only 30 percent for export. The southern pine region * * * is already past the peak of its production * * * and within ten years will probably cease to export. The Pacific Coast region alone contains more than one-half the remaining saw timber in the United States." An increasing concentration in timber manufacturing in the Pacific Coast region is not only indicated but already begun.

STUMP LANDS IN OREGON

In Oregon alone is found one-fifth of the standing timber of the United States. According to the authority just quoted Oregon has a total of 18,750,000 acres of mature timber, and 2,500,000 acres of second growth, or a total of 21,250,000 acres of land in timber. Of this, it is estimated that 10,000,000 acres in Western Oregon and 5,000,000 acres in Eastern Oregon is distinctly forest land; that is, of more value for reforestation when cut than for agriculture. This leaves approximately 6,250,000 acres, or 30 percent of our present timbered land of possible value for agriculture when cut.

In addition, as shown below, there is estimated to be at this time in Oregon 2,668,000 acres of burnt-over and logged-off land, of which 830,000 acres, or 31 percent, is estimated to be of value for agriculture. The rate of cutting in Oregon at the present time is estimated at approximately 100,000 acres per year.

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*Dean George W. Peavy, O. A. C. School of Forestry in Bulletin No. 2, Oregon State Board of Forestry.

APPROXIMATE AREAS OF STUMP LANDS, OREGON, 1920*

Western Oregon

County	Acres burned and logged	Acres agricultural
Benton	4,560	1,390
Clackamas	100,000	10,000
Clatsop	123,530	61,765
Columbia	200,000	70,000
Coos	262,965	100,000
Curry	91,000	10,000
Douglas	470,000	240,000
Jackson	32,000	10,000
Josephine	52,000	10,000
Lane	200,000	50,000
Lincoln	75,000	25,000
Linn	50,000	10,000
Marion	15,000	2,500
Multnomah	90,240	40,920
Polk	34,000	10,000
Tillamook	110,000	20,000
Washington	150,000	75,000
Yamhill	100,000	35,000
Total	2,160,295	781,575

Eastern Oregon

County	Acres burned and logged	Acres agricultural
Baker	81,376	—
Crook	3,000	—
Deschutes	20,306	—
Grant	8,987	1,000
Harney	3,000	—
Hood River	30,000	8,000
Jefferson	3,000	500
Klamath	40,000	4,500
Lake	3,100	
Malheur	338	100
Umatilla	100,000	—
Union	150,000	20,000
Wallowa	40,000	10,000
Wasco	25,000	5,000
Total	508,107	49,100
Totals for state	2,668,402	830,675

In brief, we have in Oregon, though no accurate classification has been made, possibly 5,000,000 acres of agricultural land now in timber and 1,000,000 acres of agricultural land already in stumps, and we are cutting yearly at an increasing rate. While much of this area may not be of sufficient agricultural value to justify clearing, yet **if even 10 percent of our total timbered and wooded area is good agricultural land, the reclamation of our stump land is one of the biggest and most challenging of problems in Oregon's future development.**

Much of this land is of high value for agriculture. Some of it is not excelled in richness by any now in cultivation. Some is chiefly valuable for grazing. The larger share of it comes under the favorable climatic conditions of Western Oregon, requiring neither drainage nor irrigation. Considerable areas of it are close to highways and railroads and markets. Have we feasible methods of reclaiming this land at a cost within its market value when cleared?

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*State Forester F. A. Elliott, Oregon State Board of Forestry.

In the adjoining state of Washington a recent estimate places the total area of logged-off land at 4,600,000 acres, of which 2,214,000 acres is considered agricultural land. British Columbia, on the north, and California, on the south, have further great areas of valuable stump land of similar character to that in Oregon.

POWDER AND PULLER NOT SUFFICIENT

In the pine region of the northern states, as well as in the southern pine belt—the two areas in which at present are found the largest acreage of stump land valuable for agriculture (Table, page 5) the use of powder and puller combined has proved a fairly feasible method of land clearing, and some progress in clearing and settlement of stump land is being made, particularly in areas stimulated by organized community effort.

But powder and puller in Oregon and the Northwest, while most valuable supplementary agencies, are economically not sufficient for the task. The reason for this is the great size of the stumps of the Northwest land. The average stump on typical stump land in the Northwest has twice the size of top and roots as that of the timber regions of either the northern or the southern states. While clearing with powder and puller costs in these regions from $20 to $90 per acre, here it costs from $40 to $350 per acre, with $200 per acre a fairly representative figure for typical logged-off land.

THE BIG STUMP THE REAL PROBLEM IN NORTHWEST

The big stump is the real problem in clearing the logged-off land in the Northwest and the Coast region. With ordinary methods of clearing, the cost per foot of diameter of stump increases with the increase of the diameter of the stump. The "big fellow," running from two feet to eight feet or more in diameter, and standing thirty or more to the acre, cannot be removed economically with methods now used. In other words, the cost of clearing big-stump land with present methods is usually greater than the present market value of the land when cleared, or of land of similar quality already cleared. Because of this, land-clearing in the Northwest is making little or no progress, while the area of stump land is steadily increasing at a rate that is yearly making the economic problem more acute.

The small stumps, up to fifteen inches in diameter, or the next class, up to twenty-four inches in diameter, are a lesser problem, as they can be economically removed with horse- or engine-operated puller, or with the addition of a little powder to crack or loosen and shake the dirt in preparation for the puller. It is the big stump that is prohibitive in cost of clearing.

OLD METHODS OF CLEARING

Little advance in improved agencies for land clearing has been made since the invention of the stump puller and the development of stumping powder. A discussion of the scores of methods, devices, and theories for clearing the Pacific Northwest stump land, that have been tested or advanced during the last twenty years by various men who have given this subject thought, would serve to indicate how difficult and important this problem is, but otherwise would be of little value, for it would lead to but one conclusion—that we have not yet found a method that is feasible. The proof of this lies along every highway and by-way, skirting our rail lines for miles, standing at the very doorways of our cities and towns—in the thousands of acres of fertile, attractive, close-in agricultural lands that lie profitless in stumps.

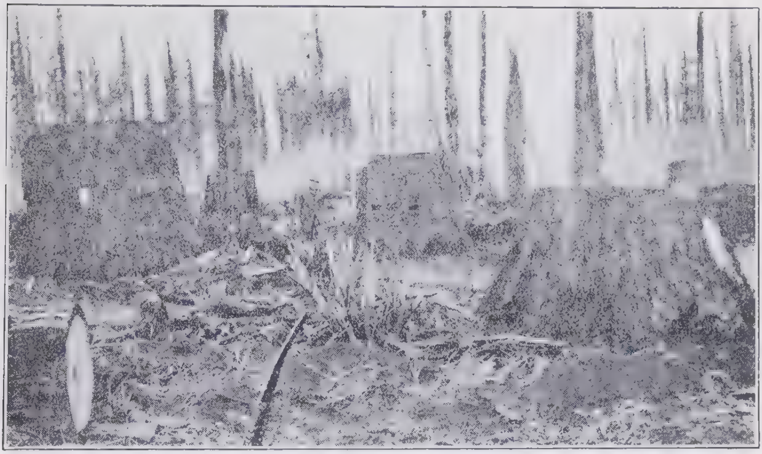

Fig. 1. Rich land but idle and profitless and a burden to the taxpayer. Twenty miles from Portland on the Columbia Highway.

Fig. 2. Clover crop just across the pavement from the land shown in Fig. 1. Market value of this land $300 per acre or better.

Hundreds of active minds have tackled this interesting problem. Some of the methods advanced have had outstanding features of value. Some have been wildly impractical in conception. But all have had faults that, when tested against the giant tombstones of our forests, have proved them unfit. Powder and puller and fire alone have emerged and remained as our sole substantial weapons, and even these, as heretofore used, have proved inadequate against the big stump—too dear in toll of labor, patience, and cash.

A NEW METHOD

Fifteen years of study and observation of land-clearing methods, the last seven devoted particularly to the study and trial of the stump burner herein described, have convinced the Oregon Experiment Station that there is a cheaper, simpler, and more practical method of clearing big-stump land than any heretofore in use. While our findings on this method in many details, no doubt, are not final, and while much corroborative and development work remains to be done, yet it seems safe to say that in this new method a definite step forward in land clearing has been made.

Let it be stated at once that this new process does not eliminate labor, hardship, and cost in removing the big stump, nor is it 100 percent efficient on all big stumps. Nature has used her utmost art and patience in the intricate entanglement of the many-fanged root mass of the tree with the earth, to rear and hold aloft the giant plant. When man attacks with equal art and a fragment of her patience and labor, he may approach her perfection, but cannot hope to equal it. The power of powder and puller has proved economically inadequate to the task, but the old art of fire in a new development gives promise of success.

That this new method does materially reduce the cost of clearing big stump lands and brings them within the possibility of economic use, that it greatly reduces the hard labor of land clearing, that it is simple and extremely practical, requires little cash outlay, fits extraordinarily well into the labor program of the farmer and settler who has the land clearing work to do, and that it gets successful results on a large percentage of the big stumps under actual conditions in which they are found, will not be denied by any who have given the method a fair trial.

To an Oregon farmer, Mr. S. F. Zysset, is due the credit for the invention of a simple but seemingly perfect appliance for the effective use of fire in destroying the big stump. The necessity of finding a cheaper and easier method than powder and puller for the big stumps on his own land was the mother of his invention.

On the completion of his device, Mr. Zysset brought it to the attention of the Oregon Experiment Station. The Experiment Station had already come to the conclusion, from an extensive study of the old char-pitting method, that the use of fire was the most promising field of study and at once became interested in the possibilities of the new appliance. Beginning in 1915, the Experiment Station has made a study of the Zysset stump burner, extending over a period of seven years, during which the development of the best methods of use of the burner on the different types and kinds of stumps and stump land and the time and cost studies necessary to indicate its economic feasibility, have been made.

In brief, it may be said that out of more than a score of devices and methods for land clearing investigated by the Experiment Station, this one alone has emerged convincingly practical, and outstanding in reduction of labor and cost of clearing.

OVERCOMES FAULTS OF OLD CHAR-PITTING METHOD

The new method may be best described as a modified char-pitting process. The old char-pitting method, sometimes called "coal-pitting," first used in Oregon some thirty years ago and extensively tested and developed both in Oregon and Washington, had one great virtue and one great fault.

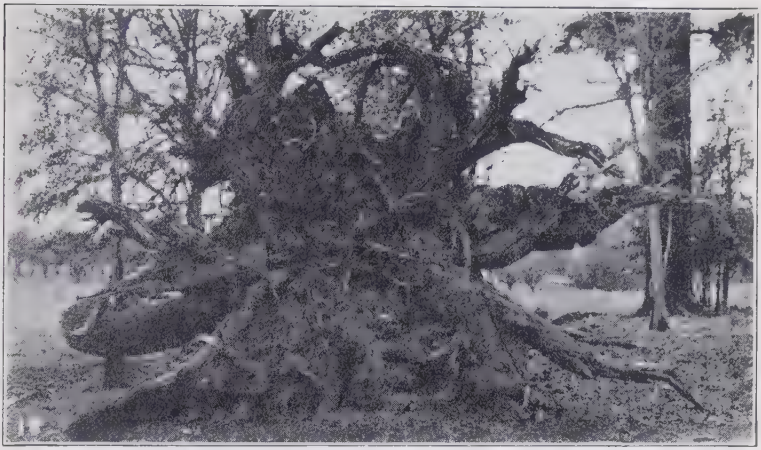

Fig. 3. The business end of a Douglas fir, a lateral rooted species. It is the massive root system of the big stump that makes land clearing costly.

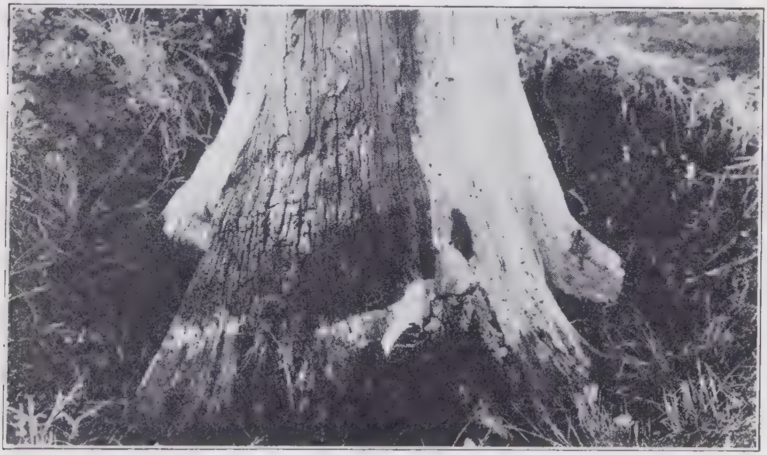

Fig. 4. Pine root crown below ground level. Pine, oak, and ash are usually tap-rooted and hence more easily burned out.

Its virtue was that, properly used, it would not only consume and destroy the big stump itself, but also the larger share of its roots to a point below plow depth. The big problem in land clearing is not getting rid of the bole or crown of the stump alone, but rather making away with the great root fangs and secondary roots extending out in all directions from the stump in the surface soil and within reach of the plow (Figs. 3 and 4). It is in clearing away the roots that the excessive cost and labor of land clearing are chiefly involved. No land clearing method that does not successfully and economically handle the root system that lies above plow depth, can be considered satisfactory. The old char-pitting method solved this feature of land clearing with marked success.

The great fault of the old char-pitting method, however, was the difficulty experienced in getting the stumps successfully afire. While the experienced char-pitter was successful with a high proportion of the stumps fired, the beginner usually lost four fires out of every five tried, and would give up the method in disgust, considering it a failure. It was a failure for the man who did not learn how to use it, and its use was difficult to teach.

A second fault of this method was that the stump was set on fire on the outside first and burned from the outside, in toward the heart, thus cutting off the central fire from the roots when the bank dropped in; hence in many cases not all the roots were burned out.

After years of effort on the part of the experiment stations in both Oregon and Washington in developing its use, the old char-pitting method has been very largely abandoned for the faults just described.

PART I. THE NEW STUMP BURNER METHOD

The new method herein discussed, by means of a simple appliance called the stump burner, first, insures the easy and thorough firing of the stump, and second, burning from the interior of the stump outward, permits far more effective burning out of the root system than did the old char-pitting method. Thus it retains the chief virtue of the old char-pitting process and overcomes its greatest faults. Any school boy who can start a fire in the kitchen stove can successfully set a stump afire with this new appliance.

The burner method is exceedingly simple and may be roughly described in a few words. By means of the burner parts (furnace, hood, draft pipes, and chimney) it is possible with ease, first, to burn a hole through the base of the stump and then convert the stump itself into a stove, and then with its own draft, chimney, and fuel, develop a fire in the stump interior so intense as to insure its combustion and the firing of the roots. When this is done the stump is banked in with earth and the crown and roots are burned out below plow depth as a char-pit. Detailed description of the procedure follows.

THE BURNER OUTFIT

A burner unit consists of the following: a furnace, two hoods, a long draft pipe, two short draft pipes, and several lengths of ordinary six-inch stove pipe. The only equipment required in using the process is a shovel, an ax, an iron furnace hook, an iron punching rod, and a wooden cleaning rod.

The furnace and two hoods are very thick walled, heavily reinforced iron castings, weighing combined about two hundred pounds. Each is open on the bottom and at the rear end and each has a shoulder on top for attaching the stove pipe. The furnace has a small draft door in the front end (Fig. 5).

The station trials have shown that such thickness and heaviness of castings are necessary in order that they will stand up under extreme heat without buckling or cracking, will not cool too rapidly when removed from the earth bank, will not crack or scale off, and will endure repeated firing without damage. The extra thickness of metal is especially important for the furnace, so that it will retain its heat while being moved from one stump to the next through mud and rain, making it easy to start a new fire in it without kindling or reheating. The arches inside the casting, aside from reenforcing the walls, are also designed as deflectors to direct the flames most advantageously for an effective fire, and especially to prevent burning out of the stump just above the furnace and the hood with resultant trouble in banking. It may be well to state here that numerous substitutes for these cast pieces have been tried (old iron plate, tiles, brick, etc.), but no satisfactory substitute for them has been found.

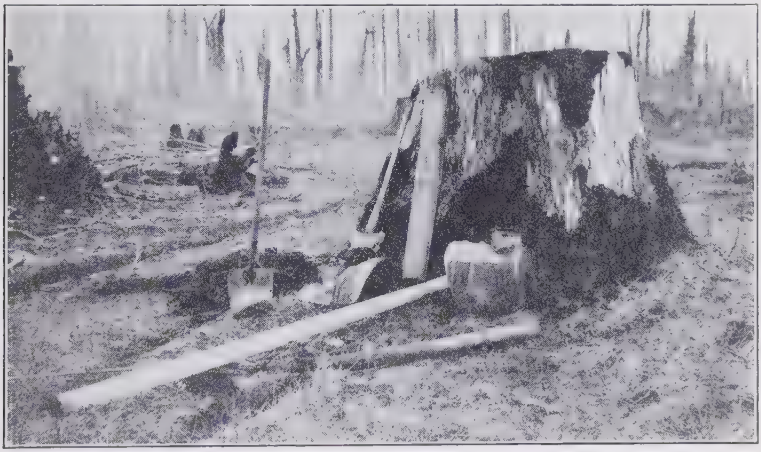

Fig. 5. The stump burner equipment. Furnace at right and hood at left.

The draft pipes are of black iron, two inches in diameter, the long pipe ten feet and the short ones four feet in length. Station trials have shown that a diameter of two inches gives the best results, smaller giving not sufficient draft and larger, too much.

The furnace hook is made of one-half-inch round iron, about three feet in length with a large rounding hook in one end and a flattened loop for hand-hold at the other.

The punching rod is of one-half-inch round iron, about six feet in length with flattened, chisel edge at one end and flattened loop for hand-hold at the other.

The cleaning rod is a slender, straight pole, about fifteen feet in length, and small and straight enough to run through the draft pipe.

NUMBER OF BURNERS REQUIRED

Depending upon the time available for clearing and the rapidity with which the work is desired done, from one to four burner units per man may be employed. The station trials have shown that four units (four furnaces and eight hoods) are usually the maximum that one man, using all of his time, can keep going. Two units constitute a desirable equipment where full time cannot be used but satisfactory progress is to be made. It would seldom be advisable to attempt work with but one unit, as the burner requires attention only at intervals and a one-unit outfit would likely be more or less neglected, and rather slow progress would be made.

KINDS OF STUMPS BURNED

In the station trials the new method has given entire satisfaction in burning fir, pine, spruce, and oak. Other species common to land of agricultural value, hemlock, maple, ash, and alder, are all good burning woods similar to those listed and should be handled successfully with the burner.

An understanding of the character of the stumps with which we have to deal, as to species, is important and is indicated in the tabulation below as reported in bulletin No. 2 of the Oregon State Board of Forestry from data of the United States Forest Service:

TIMBER SPECIES OF THE PACIFIC COAST REGION*

Douglas fir	581,847,000,000
Western yellow pine and Jeffrey pine	243,771,000,000
Western hemlock	155,614,000,000
Western red cedar	154,019,000,000
True firs	82,479,000,000
Sugar pine and Western white pine	78,622,000,000
Redwood	73,738,000,000
Western larch	28,197,000,000
Spruce	25,954,000,000
Lodge pole pine	4,566,000,000
Other species	278,143,000,000
Total	1,706,990,000,000

Of the species listed above those conifers most common to land of agricultural value in Oregon are distributed as follows:

CONIFERS COMMON TO AGRICULTURAL LAND IN OREGON

Douglas fir	255,342,000,000,	(64 percent of total)
Western yellow pine	100,000,000,000,	(25 percent of total)
Western hemlock	23,000,000,000,	(6 percent of total)
Western red cedar	15,000,000,000,	(4 percent of total)
Spruce	4,374,000,000,	(1 percent of total)
Total	397,716,000,000	(100 percent)

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*The Pacific Coast region includes the following, named in order of their total stand of timber: Oregon, 452,000,000,000; British Columbia, 350,000,000,000; California, 344,000,000,000; Washington, 268,000,000,000; Alaska, 150,000,000,000; Idaho, 98,000,000,000; Montana, 55,000,000,000.

It is clear that the chief stump with which we have to deal in land clearing in Oregon and the Pacific Coast region is that of the Douglas fir, often called yellow fir (the old growth), or red fir (the second growth).

The Western yellow pine is of much less importance in land clearing than is indicated by its stand, owing to the fact that most of it is found on soils unfit for agriculture or of relatively low fertility, although of course pine will grow and is occasionally found on good agricultural land.

The Western hemlock is of minor importance, for while found more or less on agricultural land it contains little pitch, roots less deeply, rots out very quickly, and altogether is less difficult to deal with from the land-clearing standpoint.

Western red cedar, except in deep, mellow, moist soils or bottom lands, usually is shallow-rooted and easily pulled over or cracked with powder and pulled. Furthermore, it is usually fibrous-rooted; that is, the roots are many and light and do not offer much body for fire. Frequently also the stump is hollow. Again, the wood contains an oil but no resin or pitch. For these various reasons it is doubtful whether cedar is important from the burner standpoint, and since in many of our logged-off areas cedar stumps are not frequent, no attempt has been made to burn them.

Redwood stumps, of great importance in Northern California because of their great size and high cost of clearing and the high value of much of the land upon which they stand do not occur in the Northwest states except in a very limited number in the extreme southwest corner of Oregon, and as yet have not been tested with the burner.

Spruce burns very well, especially on tideland, where it is very pitchy. Difficulty with spruce consists in the fact that it is so often high-rooted, the root bridges or buttresses standing high out of the ground, and for this reason requiring a larger amount of labor in banking. Spruce also is thin-barked and does not furnish fuel for the furnace, so that bark must be secured from adjoining firs if there be such. Since, however, the spruce is a costly stump to remove by ordinary means, the use of the burner may often be justified notwithstanding the extra labor required in banking. The total amount of spruce to be removed from agricultural land is small and is confined largely to a few counties on the Coast, particularly Tillamook and Lincoln. Unfortunately, a great deal of the most valuable land, especially in Tillamook county, has never been cleared of spruce stumps and the wrecks of these stumps, cut twenty or thirty years or even longer ago, and partly burned and rotted away, stand on valuable pasture land much in the way and costly to remove. They offer in such condition a poor place for the use of the burner. In the case of land more recently cut where the stumps are still sound and in normal condition and not too high out of the ground, and where fir bark is available for furnace fuel (frequently the case on tidelands), the spruce can be successfully handled with the burner method (Fig. 6).

The noble fir, very commonly called "white fir" in Western Oregon north of Josephine county, usually does not burn well, not even in a stove, and hence is not suitable for the burner method. The amount of this species on agricultural land is insignificant, and further, it rots rather quickly and is taken out by ordinary means fairly easily.

The sugar pine and lodge pole pine burn well but grow at the higher elevations and are not found to any extent on lands of agricultural value. The Western larch burns fairly well but is little found on agricultural land.

In general it seems safe to say that with the minor exceptions noted above, any species of stump of reasonably sound, burnable wood or of sufficient size to justify the use of fire, and with roots sufficiently large to carry a fire well (4 to 6 in. in diameter), is a desirable subject for the use of the burner.

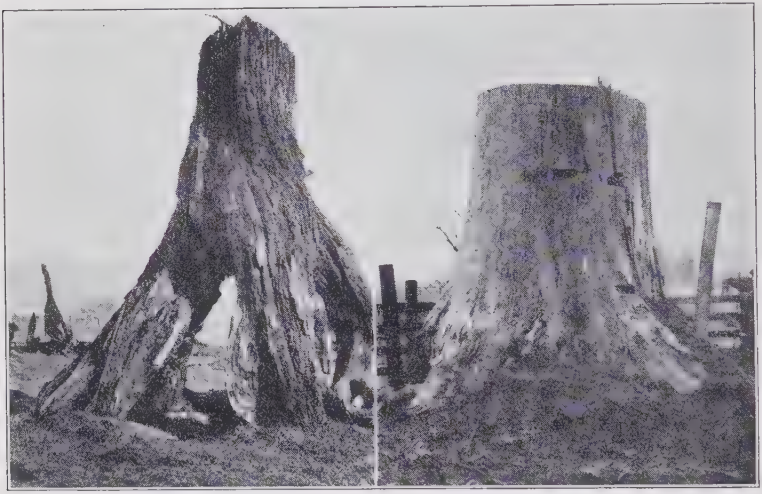

Fig. 6. Spruce stumps. At left, high-rooted wreck, difficult to burn. At right, normal stump satisfactory for burner work.

SIZE OF STUMP

The outstanding feature of the land-clearing problem in the Northwest, as already mentioned, is the size of the stumps and the excessive labor and cost of removing them through ordinary means. **The paramount value found in this new method is that the bigger the stump, the better it burns.** The cost of burning **decreases** as the diameter of the stump **increases**, just the reverse of the case where ordinary methods are used. Stumps three, six, nine, or twelve feet in diameter, the removal of which by ordinary means is usually prohibitive in cost, are those which the burner consumes most economically and completely. **The burner method is essentially a big-stump process.**

The experiment station trials indicate that the removal of the smaller stumps, those up to about eighteen inches in diameter and often, under favorable conditions, up to twenty-four inches in diameter, is best accomplished with a puller, supplemented with powder, and that the cost of pulling the smaller stumps is **economically feasible.** This fact has been well established also in other states where cost of clearing has been investigated.

The stump burner is best used on stumps twenty-four inches in diameter and larger.

In Oregon the ordinary stand of Douglas fir stumps averages about thirty to thirty-six inches in diameter, ranging from two feet to six feet or more, the average size increasing in the sections of heavier rainfall and richer soils. The average diameter and range in pine is somewhat less and in spruce somewhat more; the former being found chiefly in the drier sections of the state—Eastern Oregon—and the latter in the Coast area where the rainfall is heavier. The maximum diameter of Douglas fir on record is 17 feet, spruce 15 feet, and pine 8 feet.

CONDITION OF STUMP

The age of the stump, that is, the number of years since the cutting of the tree, is important. **Green stumps of any kind do not burn satisfactorily and should not be attempted.** Stumps of fir, pine, and other conifers are in good condition for burning at three to four years of age and from five to ten years are usually at their best. At from ten to twenty years of age, rotting of the sapwood and of the heartwood where "doty" combined with loosening of the bark and soaking up of rotted sapwood and heartwood with winter rains, make the stump slightly more difficult to bank and burn. In our trials, however, stumps thirty and more years of age have been successfully burned.

An outstanding feature of this method is that it will burn successfully both stumps and roots that are water-soaked. In a trial at Brewster, where a half of the stumps were "soaking wet" clear through, they were successfully burned. This is possible because of the slow, creeping, charcoal fire employed, which dries out the wood ahead of it as it advances. Wet roots, as long as they are above the water table and surface water is kept from running into them, will burn satisfactorily. Green wood, however, is a very different thing from wet wood. The station trials convince us that green wood will not burn satisfactorily.

Snags, wind-falls, high-rooted stumps, surface-rooted stumps, tideland stumps, hollow-hearted stumps, partly burned and partly rotted stumps, all have been successfully destroyed with the stump burner. Methods of handling these special conditions are described elsewhere. As long as the stump has sufficient sound wood remaining to furnish fuel for a good fire, the burner can be used. Stumps two-thirds rotted or burned away do not offer a satisfactory condition for the burner and are usually better removed with powder and puller. Stumps already burned off to the ground with most or all of the crown burned are best removed by ordinary means.

SOIL CONDITIONS

The character and condition of the soil are of great importance in the use of this method, since banking of the stump with earth is an essential part of the procedure.

All types of soil have been used in our trials. Only the sandy type was found unsatisfactory. Fine sandy loams, containing sufficient clay and silt to hold together when shoveled wet, will do sufficiently well, but any type sandier than these is likely to make an unsatisfactory bank, one that when heated and dry will start to run into the fire and smother it more or less.

Uncertainty on this point may be dispelled by starting a good fire with kindling against the side of a stump. When the fire has a good hold on the stump, the coals should be covered with chunk wood and then slabs of bark placed on the outside so as to give a fairly vertical outer surface, against which a bank should be laid up. After several hours, the wood will have burned away and the bank burned thoroughly dry and hot. Examination of the bank will then disclose whether it will hold up or run.

In Western Oregon, probably ninety percent of the stump lands have the heavier types of soil—loams, silt loams, and clay loams. All of these make excellent banking soil; hence the banking problem, as far as soil conditions are concerned, is difficult or preventive of this method on limited areas only.

In Eastern Oregon, the proportion of sandy soil is much higher, and the heavy pine timber stands most commonly on this type of soil. Hence it is probable that much of this area would not be satisfactory for banking. Furthermore, because of limited rainfall, the soil is moist enough for satisfactory banking only during a short period. Pine stumps cure quickly in Eastern Oregon, however, are seldom rotted or water-soaked, usually are highly resinous; it is therefore probable that the burner may be used successfully on them without the need for much banking. This remains to be determined in later trials.

Gravel is no injury in banking, unless so high in percentage as to prevent satisfactory shoveling or as not to hold together well in the bank when heated.

A wet or moist soil is decidedly preferable to a dry one for satisfactory banking. A dry soil is difficult to shovel, will not make so good a bank, and will not stand up as well.

NO INJURY TO SOILS

Does this method injure the soil? Not in the least. Seven years' use of this method in addition to three or four years' study of the old char-pitting method have given the Experiment Station convincing proof that the heating of the thin layer of soil in immediate contact with the fire does not affect or injure the soil in the slightest degree. In fact, the better drainage and aeration produced and the ashes left where the stumps have burned out cause an increased crop growth for some years following the clearing.

Fear of injury to the soil has arisen from the unquestioned damage that occurs when, in clearing with the usual method, deep piles of stumps and down stuff are collected by means of gin poles and donkey engine, or similar means, and the piles burned. The excessive, long-continued heat from the burning of these great piles bakes and clinkers the soil, damaging it to such a degree that sometimes for years it is non-productive.

In the stump burner process, however, the thin layer of soil on the inner side of the bank that comes into immediate contact with the fire drops into the pit as the stump burns out. Mixed with ashes and other unburned earth it produces a mellow, well-aerated condition. The lime and mineral plant-food elements contained in the ashes cause the crops over the areas where the stumps formerly stood to exceed in growth all other parts of the field. As a matter of fact, the outer portion of the bank never becomes heated at all and it is this portion of the bank, as the stump burns away, that is left on top of the pit, forming the major part of the remaining surface-soil cover.

SEASON OF WORK

The most satisfactory banking can be done when the soil is moist, both because the soil shovels more easily and because it forms a firmer bank. For this reason the stump burner is used in Western Oregon and Washington chiefly from October to June, during the rainy season; and in other sections, according to this condition. As a matter of fact, the stumps do not burn as well at this time, because of the wetness of the wood, as they do in the latter part of the summer when thoroughly dry; but the fact that the summer is the busy season for the farmer and settler and that the soil is hard to dig and bank at that time makes the rainy winter season the most desirable period for land-clearing work.

The heaviest rains will not prevent successful procedure with the burner. All of the Experiment Station trials have been made during the months of November, December, January, and February, the wettest months of the year in Western Oregon. A little pitchy wood and dry bark chips for kindling to start the first fires in the cold furnaces are necessary, and thereafter little difficulty is caused by rain. On low land, of course, the actual surface water must be prevented from running in on the burning stump or roots. Aside from this, the fires in the stumps are so thorough and so well maintained by the burner that rainfall does not affect them or wet wood stop them.

Dry soils, particularly of the heavier type, or where the stumps stand straight and only light banking is required, can be used with fair satisfaction as far as results are concerned, but have the objection already noted. In Western Oregon and Western Washington, however, there are only about three months, July, August, and September, when the soil is too dry for the most satisfactory banking.

Frozen ground, of course, has somewhat the same objection as dry ground, only in larger degree, in that it is difficult to dig and to make a firm, solid bank with it.

The season that comes nearest being ideal for burning is early in the fall as soon as the rains have wet the soil to the depth of a foot or so and while stumps and roots, bark and furnace fuel are still quite dry.

DETAILED PROCEDURE IN STUMP BURNING

While the burner method is simple and easily learned, the most efficient procedure to follow to gain the most successful results has been developed through the experiment station trials, carried out under many different conditions, usually against the more difficult stumps where conditions were not ideal for burning. This procedure is described below.

Selecting the Fire Route. First, the route or direction of the fire through the stump should be selected. This route should be the longest way through the stump, generally beginning on a smooth face of the stump between two main roots at ground level, and pointing through the heart of the stump toward a heavy root extension on the opposite side of the stump, if there be such, so that the fire will have to go through the longest route possible. The shortest diameter of the stump should rarely be selected for the fire route. Care should be taken also that the point at which the fire will emerge offers a good position for setting the hood.

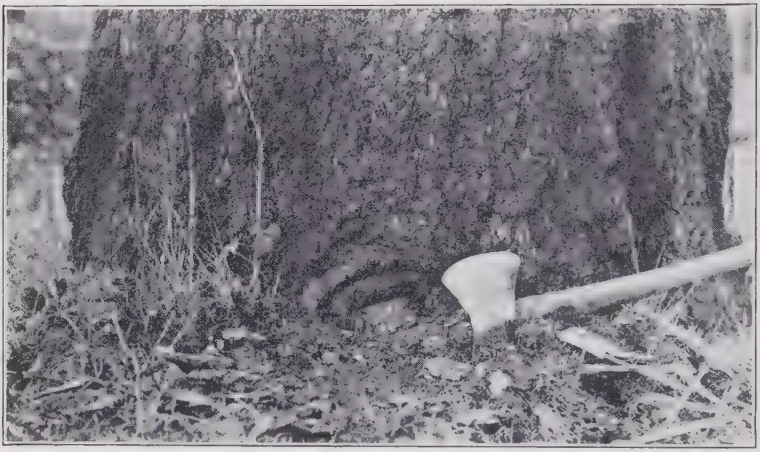

Fig. 7. The firing point. Cut through the bark to bright wood at ground level.

The Firing Point. Where the sapwood is sound and the bark tight, the next step is to cut away a hand-breadth of the bark at the base of the stump at ground level, until the bright, sound wood underneath is exposed. This is the firing point. Bark is resistant to fire, and it saves time and furnace stoking to cut through the bark to a starting point against the bright sound wood (Fig. 7).

Placing Draft Pipe and Furnace. At the firing point at the base of the stump, the earth should be leveled with the shovel, so that the furnace will set firmly on the ground and snugly against the base of the stump. Sometimes it is necessary to use the ax a little so that the top of the furnace will fit snugly to the stump. On shallow-rooted stumps or old plowed ground the furnace should be set a little above the ground level. After the furnace has been fitted, it should be laid aside and the long draft pipe should be so aimed that the fire will emerge at the opposite side of the stump at ground level at the point where the hood is later to be placed (Fig. 8). It is important that the draft pipe and the base of the furnace are parallel so that the inner end of the pipe does not point upward and fill the aperture under the deflector through which later the hot coals must be crowded against the stump face. The end of the draft pipe should be laid against the bright wood at the firing point, then kindlings of pitch wood and dry bark chips or the like should be laid over this end of the draft pipe, and then the furnace placed over the pipe, snugly against the stump. A joint of stove pipe is next placed on the furnace shoulder, and the furnace is then banked in with earth (Fig. 9).

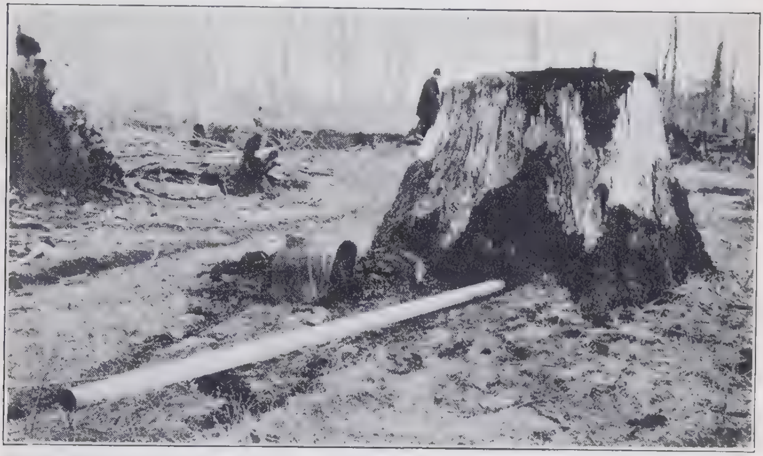

Fig. 8. The long draft pipe laid pointing through the heart of the stump, ready for the furnace.

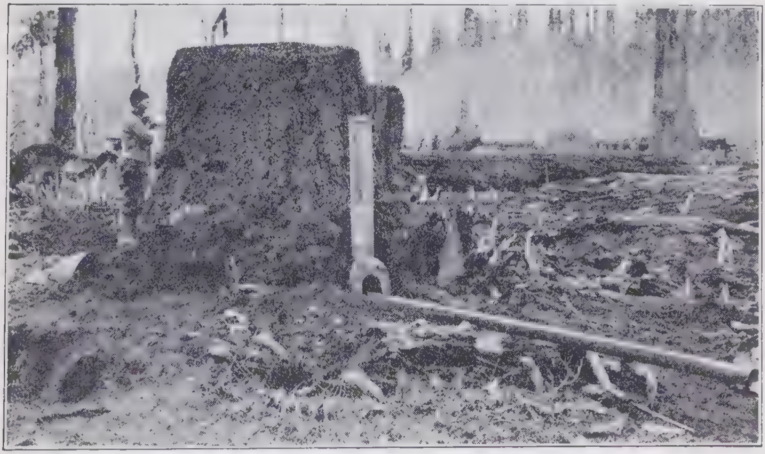

Fig. 9. The furnace banked in and ready to fire and stoke.

The banking directly over the furnace should run from twelve to eighteen inches up the stump. This portion of the bank, if the surface of the soil surrounding the stump is rather loose and light, should be made of the heavier and more compact subsoil. As the bank over the furnace is being laid, it should be tramped several times so that the furnace is tightly sealed to the stump. The fire begins at this point on the stump and burns here longest, hence it is likely to burn out above the furnace unless well sealed in this way.

After the furnace has been banked in, **the face** of the bank over the furnace should be carefully cut away sufficiently to prevent the earth coming in contact with the stove pipe, as this contact causes the pipe to burn out at the point touched. Ordinarily the stove pipe will last pretty well through the season. It holds up better if riveted.

Stoking and Firing. After the furnace has been banked in, the draft pipe should be pulled back slightly so its inner end is about two inches from the bright wood of the stump. The kindling is then lighted and when well started, the furnace is filled with chunks of bark usually taken from the stump itself. These chunks are tossed in through the chimney opening and crowded back with a stick, so that the furnace is packed tightly to the door and to the top, with bark. The chunks of bark will make the best fire if packed in either edgewise or with the outer side of the bark down.

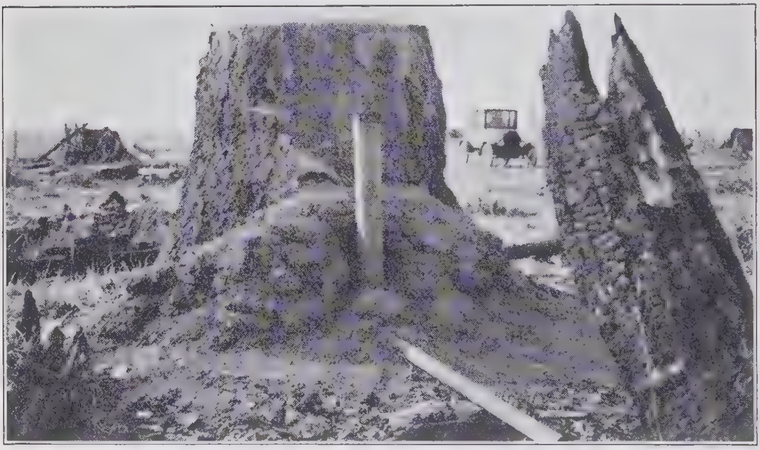

Fig. 10. Fire going well and furnace door closed with earth. Fire blast from draft pipe now burning hole through stump.

When the furnace has been thus stoked, one or two joints of stovepipe are placed on the chimney shoulder so that a good draft is created. Sometimes with a high stump and the wind blowing over it, or with a pitchy stump, an extra joint of stovepipe is added to give good draft.

As soon as the first stoking is burned half away, the stovepipe should be lifted off, **the coals pushed well back (beyond the deflector) directly against the stump base** and the furnace refilled with bark, and the chimney replaced. As soon as there is a good bed of coals in the furnace, usually after the second stoking, the draft door of the furnace is closed with about two shovels of earth (Fig. 10).

The suction of the fire up the chimney now pulls the air through the long draft pipe with considerable force. The end of this pipe lying in the bed of coals is red hot and a blast of flame is thrown against the base of the stump and a fire hole is started into the stump. Until this hole is well afire, it is necessary to restoke the furnace several times. In the station trials on wet stumps and in wet weather, it was found necessary to stoke or fill the furnace on the average a total of four times before the stump itself was sufficiently well fired to make further stoking unnecessary. Less stoking is necessary under more favorable conditions. New fires should not be started later than mid-afternoon.

It was found that bark made decidedly the hottest and most lasting fire and was most convenient for furnace stoking. Where bark for fuel is not available on the tract to be burned it is usually possible to secure a load of bark from adjoining land. A few hours' work will usually secure enough bark to provide furnace fuel for several weeks of burning.

Advancing the Draft Pipe. As the fire advances into the stump the draft pipe is pushed forward so that the end of the pipe is kept from four to six inches back from the burning face in the stump. The **condition of the fire at any time may be easily judged by looking through the draft pipe** or noting the intensity of the heat from the chimney. Should the draft pipe become stopped up with earth or ashes, the cleaning rod should be used to free it, or it may be pulled out and jarred empty.

In dry, sound stumps the fire advances from two to three inches per hour, while in wet or pitchy stumps it advances only one inch or less per hour; hence it is necessary to push the draft pipe forward only three or four times a day. Before pushing it forward the first time, a stake should be set at the outer end of the pipe so that the distance the fire has advanced and the time it will emerge on the opposite side of the stump can be more easily judged.

In advancing the draft pipe, it is well to push it in until it touches the burning stump wood, and then pull it back about three or four inches. In this way the distance of the pipe end from the burning wood can be more accurately gauged. Speed in burning through the stump and hence maximum use of equipment are aided by advancing the draft pipe more frequently. The end of the draft pipe, however, should not average closer than four to six inches from the burning wood surface, as being too close tends to reduce the fire blast from the end of the draft pipe. On the other hand, little harm is done if the draft pipe is not watched closely and advanced promptly (as for example, when left over night), since the result is merely to burn the hole in the stump larger in area but not quite so fast forward.

Placing the Hood. The station trials have shown that on the average three-foot stump, the fire burns through the stump to the opposite side in from twenty to thirty hours. As soon as the distance between the stake and the outer end of the draft pipe shows that the fire has burned nearly through, the stump should be kept under observation, so that as soon as the fire appears on the side opposite the furnace, the hood may be snugly set and fitted over the burned opening. When this is done a joint of pipe should be placed on the hood and the hood banked in firmly and sealed tightly, as was done with the furnace (Figs. 11 and 12).

Where it seems likely that the fire will burn through over night, it is often advisable to put the hood over the point on the stump at which the fire is expected to emerge, put the joint of stovepipe on it and bank it up, so that if the fire should burn through during the night, it will be properly confined by the hood and not burn too large an orifice in the side of the stump for the hood to cover satisfactorily. Where a large orifice has been burned waste wood should be used to fill up the fire cavity and the hood set higher on the stump on an earth base.

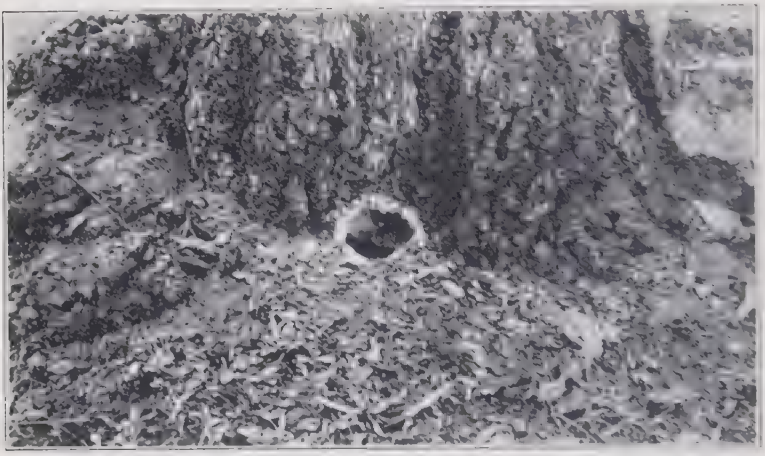

Fig. 11. Hole burned through stump ready for hood. Note end of draft pipe inside.

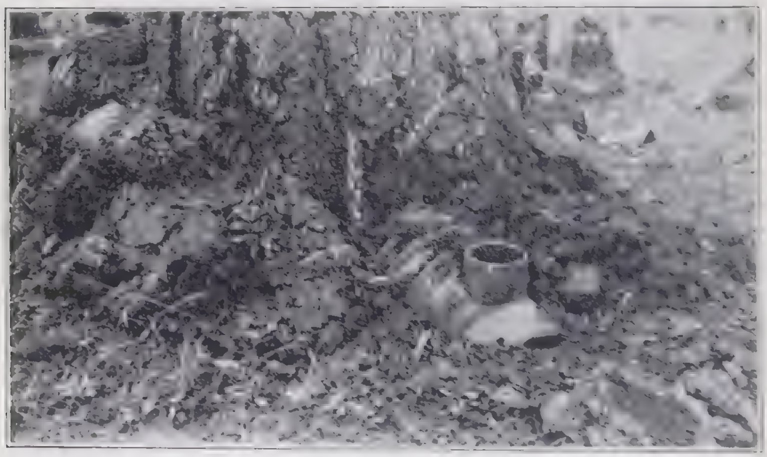

Fig. 12. Hood placed and ready to bank in.

Removing the Furnace. After the hood has been placed, the long draft pipe is removed and a short draft pipe laid in its place. (The long draft pipe is carried away and laid in position at the next stump, which has already been prepared for the furnace.) The bank directly above the furnace is carefully removed; or better, if it appears solid enough to stand, it is left intact. The hot furnace is then carefully loosened from the bank, pulled away with the furnace hook and skidded quickly to an adjoining stump, where it is packed full at once with fuel, is banked in, and goes immediately into action without the necessity of kindling any fire (Fig. 13).

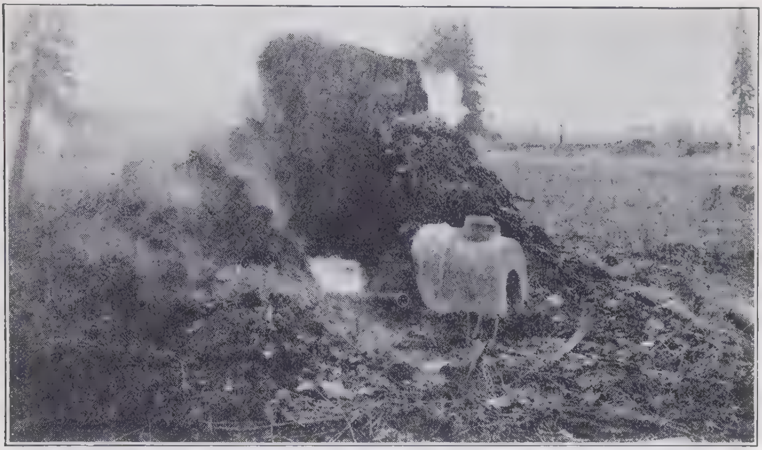

Fig. 13. Furnace removed, short draft pipe in place, orifice ready to close and bank in.

In the opening on the first stump, from which the furnace has been removed, a heavy chunk or two of wood is pushed in endwise to fill the orifice. The short draft pipe is put in place, and some heavy pieces of bark are used to fill or cover the opening. The inner side of the bark should be put toward the fire. The furnace opening is then banked in, the bank being **laid up** carefully so that it will stand. The short draft pipe now extends through the bank into the stump at the place where the furnace stood. The remainder of the stump is then banked. **The stump has now been converted into a stove with a draft on one side and a chimney on the other and furnishing its own fuel** (Fig. 14). The result is inevitable. Usually within forty-eight hours after the hood has been placed, so great a mass of fire develops on the interior of the stump that the hood and short draft pipe may be removed, the hood opening banked in, and the stump left to finish as a char.

Removing the Hood. As indicated, as long as the hood is left on, the stump is burning under draft. Just how long this drafting should be continued is a matter of considerable importance and not easily judged. Usually the tendency has been to leave the hood on too long. In our trials a number of stumps were burned successfully without using the hood at all. On some it was used only a few hours. On most it was used an average of forty-eight hours.

As previously stated, the primary object of the burner is to set the stump thoroughly afire and produce a great mass of glowing charcoals in the heart of the stump. This charcoal burns very slowly, if allowed only such air as seeps in through the earth bank. Burning thus slowly, it constantly adds to its mass, extending out toward the roots and gradually extending into each one of them, if there are no earth obstructions. This glowing mass of charcoal produces and holds an immense amount of heat, and when replenished by the fuel contained in the great root crown under the center of the stump, the heat and fire endure a long time, radiating outward towards the roots and penetrating and drying out the wet wood, driving the fire slowly into the roots.

It can be seen readily enough that, if the hood is left on too long, a considerable portion of this charcoal mass is burned away through the access of air from the draft pipe and the too rapid combustion thus permitted. The most likely result will be first, an uneven burning away of the top of the stump, so that the top will not settle into the pit evenly, and second, less certainty of thorough connection of the central fire with all of the roots.

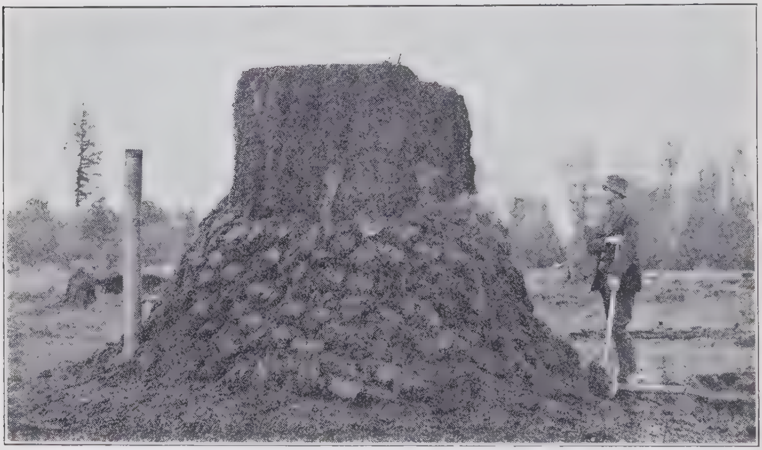

Fig. 14. The stump is now a stove with draft on one side and chimney on the other. A simple, natural, economical method that gets results.

It is therefore considered advisable, once the stump is thoroughly afire and a great mass of coals has been produced, to remove the hood and short draft pipe without delay. On the sandy types of soil it is especially important not to draft (that is, leave the hood on) too long.

When the hood is removed, if it is observed by probing with the punching rod that the bed of coals is shallow and considerably burned away, it is advisable to chunk the cavity well in order to replenish the bed of coals before closing in the bank. It is sometimes worth while, also, to punch down the charcoal from the roof of the cavity.

Banking. Either after the furnace has been started, or at the latest, after the hood has been placed, the remainder of the stump should be banked in. This work is not hard, nor does it take long—seldom an hour on the larger stumps and much less on the average stumps. The work, however, should be done carefully, and there is a certain knack to good banking. On the average land, which is of a heavier type, the surface soil surrounding the stump is used.

Setting the shovel vertically, the soil can be taken up in unbroken shovelfuls and the bank laid and built up around the stump somewhat as a mason lays up a stone wall, each shovelful supported by those underneath, fitting snugly against the stump base, but not depending on it too largely for support. To accomplish this, the earth must not be thrown on the bank, but laid on in unbroken shovelfuls. The base of the bank is made several shovels wide, and each shovel of earth is laid so that the bank top is kept horizontal rather than sloping against the stump, and also so that the "joints" between shovels of earth are "broken," that is, each shovel of earth overlaps and binds on the next one. Again each shovel of earth as it is lifted is turned over as it is placed on the bank and brought down with a slight slap, so that it is brought firmly into place and into good union with the bank underneath.

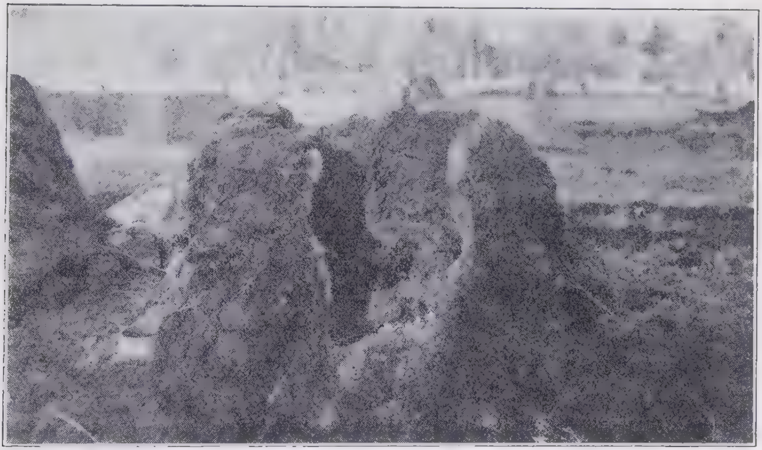

Fig. 15. The stump has burned off and settled down. Bank has been left erect and segment cut away to show how a well-laid bank will stand up.

The whole idea of banking should be to lay up a bank that will almost stand by itself, so that as the stump inside of it burns away, the bank will not fall in (Fig. 15). The fire inside the bank tends to bake an inner crust on the bank earth, and this helps it to stand up, except in a sandy type of soil, which is likely to run more or less when heated.

The height of the bank rarely need be more than 24 to 30 inches above ground level. Only in old, low, badly rotted stumps need the bank extend over the top of the stump.

The bank should not be made air tight or too thick (about 12 inches at base and 5 inches at top), or, on soils of the heavier type, should not be packed, except directly over the furnace and hood and around the top layer, where it is sealed to the stump by firmly pressing with the foot. The slow seepage of air through a well-laid bank is just sufficient to supply the limited oxygen needed for charring.

In all banking the soddy surface portion of the shovel of earth should be laid crosswise of the bank to aid in binding it together. The grass should not be laid directly facing the stump, especially in the lighter soils, as the burning away of the grass roots causes the bank earth to "run" more readily.

In the lighter types of soil which do not hold together so well, better banking material is secured by throwing aside the surface soil and using the more compact and heavier subsurface or subsoil. Where, as in the Coast counties, there is a light, fluffy surface soil with a good deal of small ground growth, such as salal, so that it is difficult to get solid, unbroken shovels of earth, it is best to throw aside the surface soil and use the more compact subsurface soil. With these light soils the inner side of the bank should be tramped more or less to make the bank more compact.

In "shot" soils, where the "shot" formation is so abundant as to cause the soils to "run" when the heat comes against the bank, it is advisable to tramp the inner side of the bank against the stump sufficiently to "firm" it and thus help to prevent running. Here, also, the firmer subsurface soil often can be used to good advantage for banking.

In the lighter or sandier types of soil, where a heavier subsoil is not available, tramping the inner side of the bank is of considerable benefit. Soils sandier than a fine sandy loam do not bank well, as they run when burned, thus shutting off the fire from the roots before they are well started. In such soils the stump-burning method cannot be used very satisfactorily. The proportion of such light soils on our stump lands, however, is very small.

Banking Roots and Root Bridges. Where, as in the spruce in the Coast counties, the main roots extend well above the ground, sloping or bridging outward (buttressing) from the tree bole to the ground, it is necessary to follow in and out around the root extension in banking, finally bringing the bank around the root extensions up to meet the main body of the stump. These high-rooted stumps cause a good deal of extra work in banking and must be watched in burning, as the bank over the sloping root bridges falls in readily.

On lands where the water table is high or subsoil unfavorable or for other reasons the stumps are surface-rooted, sometimes running for some distance above ground, it is necessary, wherever the root shows, to bank it over with earth. Otherwise, when the fire in the root reaches the exposed area, it will quickly burn out.

Confining the Fire. Confining the fire, keeping it under the earth bank at all times, and at all points, is an absolute essential to the success of this method. The primary object in this process is to produce and maintain a great mass of glowing charcoals in the heart of the root crown. From this mass the fire radiates and creeps slowly down the roots, drying the wet wood ahead of it as it goes. It is this mass of coals and slow, creeping, smoldering fire that make this method so successful in burning out the roots, making the land ready for the plow with little further effort.

This mass of slow-creeping fire is absolutely dependent for maintenance upon the covering provided by the earth bank which reduces the oxygen supply, thereby causing the formation of charcoals instead of more rapid combustion which would quickly burn the interior of the stump away. Let the air have ready access to the fire through a broken or leaky bank and flames and rapid combustion ensue, the stump fuel burns away, and the fire dies before there is time for it to take hold and get well started in the root system. Flames or blue smoke appearing at any point are a danger signal and indicate always that the bank should be replenished or mended and the fire sealed in. The operator will soon learn to distinguish between the thin, bluish smoke which indicates rapid combustion and the need for bank mending, and the white, steamy smoke which comes normally from points in the bank as the moisture dries out, which need cause no concern.

THE CHAR-PITTING END OF THE PROCESS

Of particular importance in successful stump burning is mastery of the art of char-pitting for completion of the burn. With the removal of the hood, the next step in this method begins—the burning out of what remains of the stump and root by means of the char-pitting process. Success with char-pitting requires understanding and judgment and very little labor. Instructions for it are not easily given. Though those experienced in the old char-pitting method will have little difficulty, the beginner will need to be watchful and learn as much as possible from the experience of others, as well as from his own experience.

Under average conditions, four out of five stumps will go through the charring process satisfactorily if the simple procedure outlined below is followed.

The fundamental and governing principle in successful char-pitting is to keep the fire confined but yet not smother it.

After the hood has been removed and the bank closed in, the fire within the stump burns toward the outer edges or perimeter and no attention need be given it until flame or blue smoke appears at any point (Fig. 16). Usually the stump will burn through somewhat unevenly so the fire will reach the bank at one side before the rest of the stump perimeter has burned through. When the fire meets the bank, it works upward and breaks out at the top. Earth, or preferably sod, should be laid on the bank at that point until the bank is built up again to cover the fire, care being taken not to break the bank or push much of the bank earth into the fire. If blue smoke appears on the side of the bank, loose earth may be used to thicken and close the leak. If a large portion of the bank falls in, the fire should be chunked through the orifice, heavy pieces of waste wood being pushed in until a surface is formed against which bark may be laid and new bank built up.

Usually in two to four days after the hood has been removed, the entire base of the stump will have burned through and the top will settle down into the pit below. The added fuel replenishes the bed of coals below and aids the root fires (Fig. 17).

As the top of the stump settles down, it should be followed up with the earth cover, pushing in the hot bank earth against the wood and adding fresh earth where necessary to keep the fire confined. As the stump top sinks below the top of the bank, the bank should be tumbled over on it and enough fresh earth added to cover and close in the entire surface. This cover, however, **should not be heavy or tight.** It should be only four or five inches thick, and loose, so as to allow the fire some seepage of air. Too tight a cover will smother and stop the char. The hot bank soil makes the best cover, and usually little fresh soil will be needed.

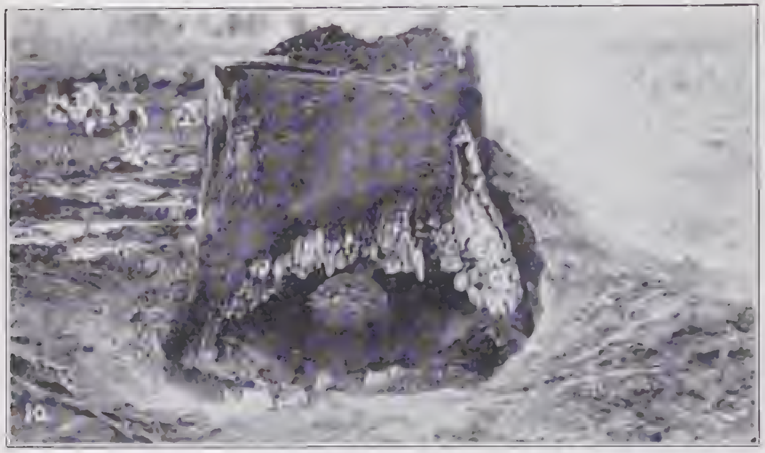

Fig. 16. The bank has been purposely removed to show outer edges of stump practically burned away, stump ready to settle down into pit.

Fig. 17. Looking down into crater, showing top of stump settling down into pit, ready to follow in with bank.

Gradually the fuel, the stump top, and the root crown under the earth cover, burn away; and in a week or two, sometimes much longer, a considerable depression or pit develops over the center of the stump site, as the earth cover sinks in. It is important not to disturb this mound of earth. For several weeks the outer portion of the mound will be cold to the touch and it will appear as if the fire has died out. By using the punching rod as a probe, running it down into the mound, it will be found usually that there is considerable heat at the center or edges, and if this is the case, the mound should not be disturbed. In four cases out of five, the roots will be burning out satisfactorily.

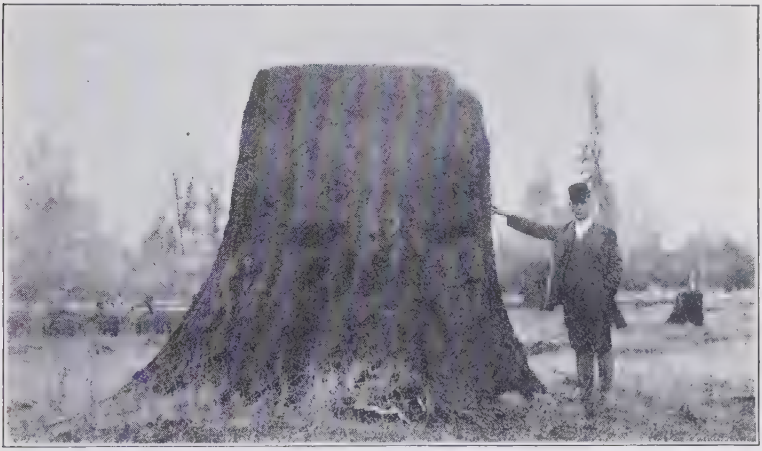

Fig. 18. A big fellow and the man, Mr. S. F. Zysset, who invented the device to destroy it.

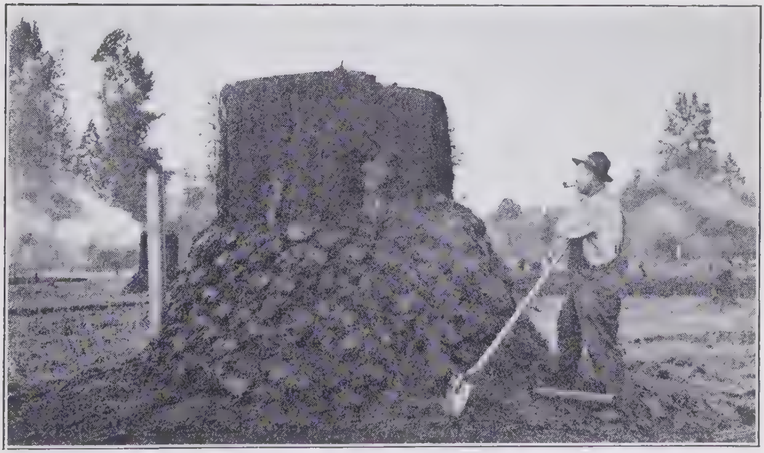

Fig. 19. Same stump as in Fig. 18. The stump is now a stove.

Occasionally, probing will show no signs of heat. Sometimes this means that the coals have been covered too deeply, and punching a few holes with the shovel handle will give needed ventilation, but usually little further can be done, and it is always inadvisable to dig away the cover to see what is happening. Some of the roots may be afire in good shape, and this would only disturb and risk their going out.

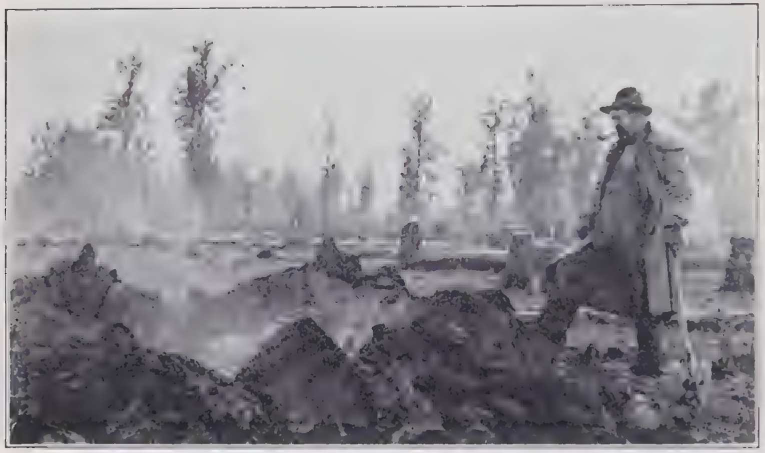

Fig. 20. Same stump as in Figs. 18 and 19. The last fragment of the stump may be seen burning away in the center of the crater.

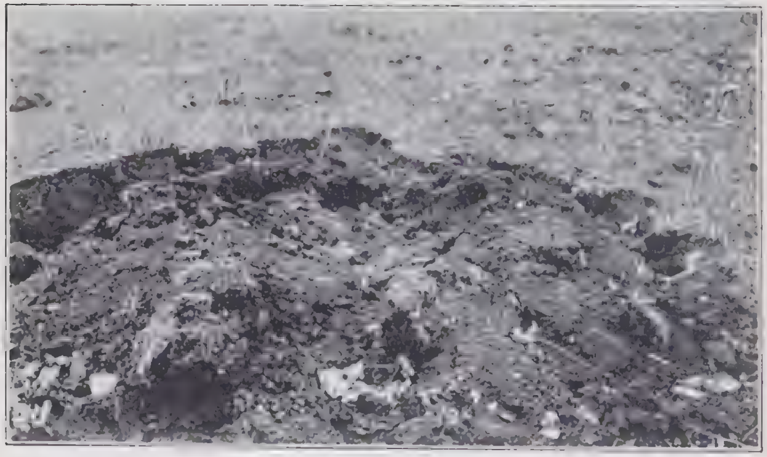

Fig. 21. Done, and ready for the plow—just a low mound of earth and ashes.

Usually, in three or four weeks, but often not for five or six weeks and sometimes more, the roots will have been consumed and the job is done. (Figs. 18, 19, 20, and 21.)

SPECIAL CASES

High Cuts and Stubs. Sometimes, particularly on high-cut trees, the stump will burn off unevenly and roll off to one side. Where this occurs, it is best to throw a considerable layer of waste wood on the fire, let it start burning vigorously, and then cover it over with earth. The top portion of the stump that has fallen to one side usually may be easily consumed by throwing enough waste wood in the "cupped" end from time to time to keep it burning.

Where the stump top burns away at one side, only a stub sticking up, it is important to chunk the coal bed or cavity underneath the stub and cover with earth, following up the remnants of the stump with earth to keep the fire below sealed in, so that it will follow down the roots on the unburned side.

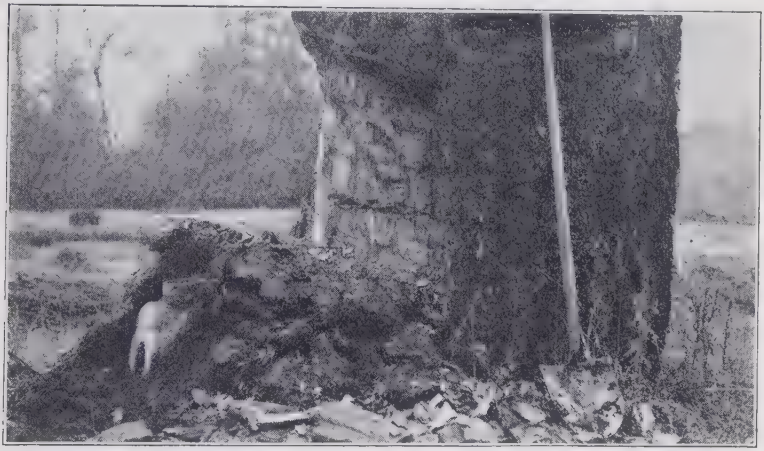

Fig. 22. Bark and rotten sapwood cut away so that the bank can be sealed to sound wood.

Where Sapwood is Rotten. If the stump is old and sapwood rotted so that the bark is loose, the bark and rotten sapwood should be cut away in a circle around the stump in a band about a foot in width at the height above the ground (usually twenty-four to thirty-six inches) where the bank is to be topped off and sealed against the stump (Fig. 22). The top of the bank can then be sealed tightly against the sound wood, thus preventing the escape of fire at this point. If the bark and rotten sapwood were left at this point, the fire underneath would soon burn the sapwood away and the flames would break out between the inner side of the bank and the stump. The free access of air thus permitted would cause rapid combustion of the sides and top of the stump, destroying the bed of coals underneath upon which the firing and burning out of the roots depend.

Value of Bark. While it is essential to cut a band of bark and rotten wood away where the bank is to be topped off, it is equally important to leave the bark on the stump below this point. This lower bark holds the bank in place, as the fire advances from the center of the stump towards the outer edge or perimeter. Bark is resistant to fire and slow to burn. This lower belt of bark will stand as a supporting shell or wall inside the bank, preventing it from falling in before the stump burns off and settles down into the pit. If parts of the bank fall in long before the main part of the stump settles down, the earth acts as a dam in cutting off the heart fire from the roots at that point, and is likely to prevent such roots from being well fired.

Where no bark remains on the stump, the rotten sapwood should be cut away to the level of the ground, so that the bank all around the stump will be in contact with the sound wood.

Hollow or Wind-shaken Stumps. Where the stump is hollow in the center and the hollow runs well down toward the root crown, this opening should be well packed at the bottom first with chunks of bark, if available, and then with other chunk wood, and then covered at the top with well-packed earth, a layer five or six inches in thickness. This will prevent the hollow in the stump from acting as a chimney and the fire emerging from the top of the stump before the base of the stump has been burned through.

If the stump is cracked from wind-shake, or has a pitchy heart, or pitch seam extending to the top surface of the stump, a six-inch covering of well packed earth should be laid over the top of the stump to seal it shut.

Pitchy Stumps. If the stump is especially pitchy, it will burn more slowly, and creosote and soot may accumulate in the stovepipe and even in the furnace and fire hole. In this event, it is usually sufficient to open the draft door of the furnace occasionally by removing the earth placed over it, letting the creosote burn out with the brisker draft thus created, and then the furnace door is closed again. Occasionally, soot and creosote will collect to such an extent in the furnace and fire-hole itself that it is necessary to use the punching rod to stir up and burn out this accumulation.

Hardwood Stumps. Hardwood stumps do not take as long to burn out as do the conifers. When the furnace is removed the furnace opening often is not closed but is left open, since hardwoods need more air to burn well. The hood is usually left on only about ten hours. Hardwoods usually burn out completely in four or five days.

Snags. The procedure with snags is the same as for other stumps. When they burn through they will topple over, and if of large diameter, may be burned in place, as described elsewhere for logs.

Windfalls. Usually windfalls are difficult to handle through ordinary means because of the weight of earth they carry. The burner can often be used on them to good advantage. It should be set to burn diagonally through the upset root crown, starting in at a point in the trunk about two feet above the root crown. The fire route should be banked in, but frequently it will not be necessary to use the hood. A large part of the mass will be burned away and the remaining fragments much more easily handled (Figs. 23 and 24).

Partly Burned Stumps. Where logged-off land has been run over by fire several times, many stumps will have been partly burned. This makes them more difficult to handle with the burner, as often bark is not available for stoking, and the unevenly burned tops are hard to bank so as to bring a fire through to all of the roots. On such stumps the burner should be set low in order to fire the base of the stump and as possible. The furnace is usually started against any remaining stub root crown in those parts of the stump from which the top has been burned away. It is usually desirable to pile and pack closely large and small chunks of waste wood above the root crown where the stump top has been burned away and then bank in and cover as carefully

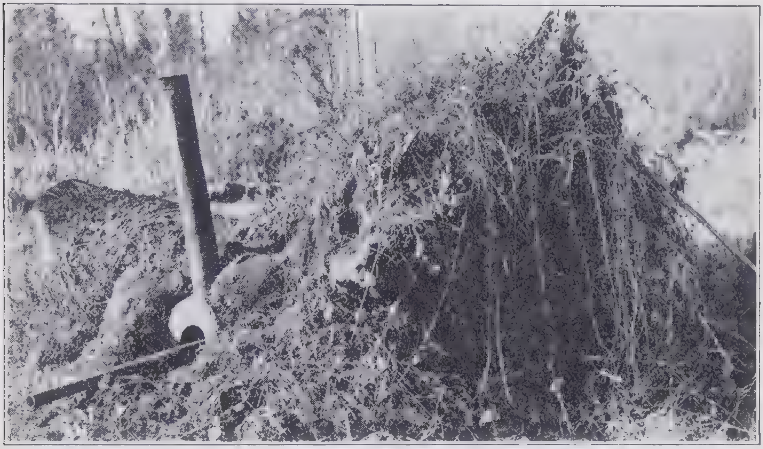

Fig. 23. Furnace set on an old windfall.

Fig. 24. Windfall shown in Fig. 23, almost completely burned away.

of the stump, the draft pipe being directed through the heart of the crown as usual, except that the furnace is kept low by digging away the soil where it is placed. Bark for stoking may advantageously be brought from adjoining land, if heavy fir bark is convenient, as bark is decidedly superior to anything else in heating and convenience for stoking.

Water Pockets. Sometimes a partly hollow stump will contain a reservoir of water. If this is noted, it should be drained off by boring in from the side at the base of the pocket with a wood auger.

If the pocket is concealed and the water drops down on the fire when the bottom of the pocket is reached by the fire, putting it out, the furnace should be withdrawn and moved to the opposite side of the stump and a new fire started in from the opposite side, the first opening being chunked and then the hood banked in where the furnace first stood.

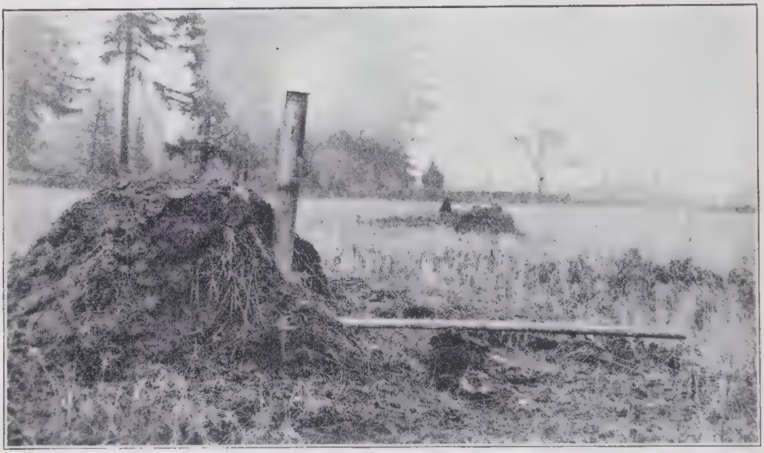

Fig. 25. Old, badly rotted stumps, if low, are banked clear over the top.

Rotted Stumps. Stumps rotted so completely as to offer insufficient sound wood for a good fire should be blown out with powder, unless sufficient sound wood remains at the base, when sometimes by digging away a pit and trench and putting the furnace low, a fairly good burn can be made.

Stumps badly rotted, but still burnable, usually have to be banked completely over the top (Fig. 25).

Tideland Stumps. These are usually spruce, and often with tops burned away almost to the ground level. They are nearly always very pitchy, because of the high water table. They are often burned in summer when the water table is down. On such stumps successful results have been obtained by digging a pit for the furnace and hood and a trench for the draft pipe and putting the furnace below the ground level. The top of the root crown may be covered with waste wood and banked in and covered over as well as possible. Tideland stumps not partly burned but intact are handled in the regular way and usually burn out exceptionally clean.

Earth Dikes. Often a wedge or ridge of earth will extend up underneath the root crown between interstices of the root sufficiently to obstruct the fire blast from the furnace. When a look through the draft pipe shows no fire directly at the end of the pipe, although the pipe has been cleaned of any possible earth by use of the cleaning rod, it is quite likely that the draft pipe has come against an earth dike. Punching the draft pipe against this dike will indicate usually whether it is an earth dike or not and sometimes the punching will break through it and the fire blast will resume its work. If not, the draft pipe may be deflected upward or to one side and thus burn past the dike. If this cannot be done, it may be necessary to remove the furnace and punch away the dike with the iron punching rod. When this is done, the cavity should be refilled with waste wood, the furnace replaced and the fire started again. Occasionally it may be necessary or desirable to move the furnace to the opposite side of the stump and start again from that point (Figs. 26 and 27).

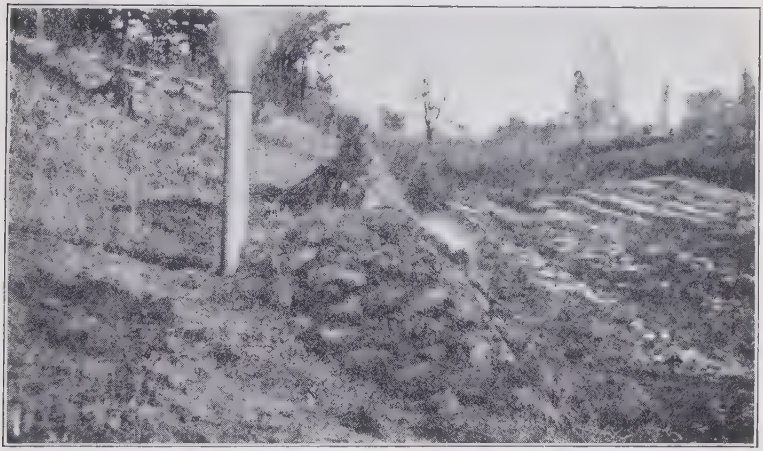

Fig. 26. Hood on four-foot pine on side hill. Furnace set at lower side, used 24 hours and hood only 12 hours.

PREPARATION FOR CROPPING

After the burning is completed, and it is certain that the root fires have burned out, a good procedure is to take a light plow and plow first a shallow and then a deep furrow close around each stump to determine, where no visible signs of main roots remain, whether there are any that have not burned away below plow depth. Some, of course, will be found. These may be removed with team and chain or loggers' hooks or root plow with block and line. Where the stubs of stumps with root attached remain, a fire may be built against them and banked in and the root burned out, or a little powder may be used to loosen them for pulling.

When all seems clear, a little work with the shovel to level down any parts of the mound that may remain is usually all that is required. Where the stumps have been numerous and close together, so that the banking has left the ground uneven, a log or timber drag of some sort or a scraper may be used to level down the surface sufficiently. Then the ground may be plowed, dragged, disked, and dragged again until in condition for seeding. Oats or potatoes make an excellent first crop after clearing.

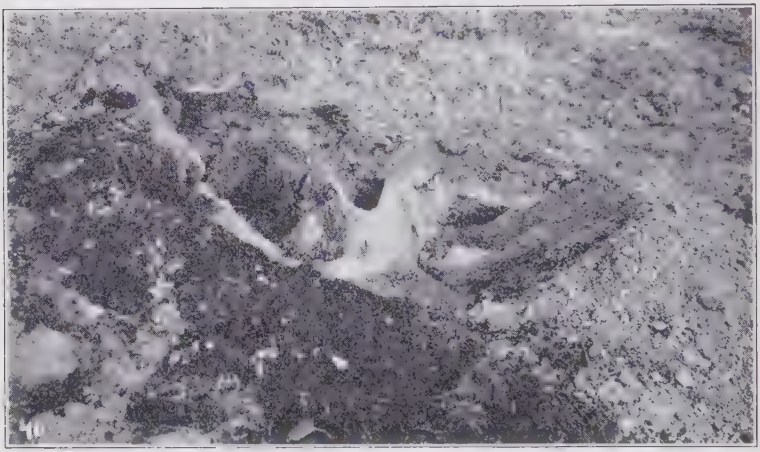

Fig. 27. Same stump as in Fig. 26. Two weeks later, earth removed to show roots burned out completely, three feet below ground. Note earth dikes in center.

COST DATA

Stump Burner Method. The investigations of the stump burner method made by the Experiment Station indicate clearly the reduction in cost of clearing big stump land by this means. Of the three cost trials made, one was under average conditions as to age and condition of stumps and character of soil and two under extremely unfavorable conditions, which tested the limits of the possibilities of this method. In addition to the three cost trials fifteen other field tests of the method were made in as many different localities and conditions in Western Oregon, corroborating the findings in the main trials.

In the first two trials the time and the cost were obtained (1) for banking and burning the stumps, (2) for finishing up for the plow. In the third trial a detailed record was kept of the condition of each stump and the labor and time required for each phase of the operation on each stump.

In all of the cost data submitted below it should be clearly understood that the costs of clearing shown are for the removal of the big stumps only. Surface clearing and removing the smaller stumps are not included. The cost of this part of the work varies from $5.00 to $25.00 per acre though rarely as high as the latter figure. Furthermore, the cost of this part of the clearing is the same whether the big stumps are burned or removed with powder and puller. The great reduction in the cost of clearing with the burner method is in the removal of the big stumps, which are the controlling factor in Northwest land clearing.

Necessarily as the method was entirely new when its study was undertaken by the Experiment Station much experimenting to determine the best method of use was done in all of the trials. The results of the trials are briefly summed up below.

Trial No. 1, Jefferson, 1915

In this trial made in November and December, 1915, the cost was determined of clearing the land of 196 Douglas fir stumps, ranging from a minimum diameter of 20 inches to a maximum of 66 inches, with an average diameter of 39 inches.

Owing to ignorance of the best methods of use, this first trial was largely experimental in nature and not representative or conclusive as to cost. Certainly every condition was extremely unfavorable to the successful use of the method.

(1) The soil was a light, sandy loam very unsatisfactory for banking. Further, it was old plowed land, loose, and with no sod to help in banking. The bank "ran" or fell in and cut off the fire from the roots in many cases.

(2) (a) The stumps were all old, cut twenty years or more, badly rotted in the heart and sapwood so that all the bark remaining had to be removed and nearly all the stumps had to be banked clear over the top. (b) They were thoroughly soaked up with the heavy rains of November and December and in some cases the water table rose into the root crown during the trial. (c) From long plowing around them, the stumps nearly all "sat high" above the ground level of the fields, frequently causing the furnace, through our ignorance, to be set too low on the root crown to do the best work. (d) Most of the stumps were surface-rooted, making it more difficult to drive the fire into them than if they had been well covered.

(3) As stated, the best method of use of the new burner had not as yet been worked out and many costly mistakes were made in this first trial on this account.

Only our ignorance of the best use of the new method permitted us to make such a poor selection for an initial trial, and only the fundamental soundness of the method itself made it possible to bring the trial through successfully. While this trial taught us many things we ought not to do, it also cost us heavily in the later removal of unburned roots for not having done these things. On completion of the burner work it was found that:

On 68 stumps 85 percent of the roots were burned out.
On 105 stumps 55 percent of the roots were burned out.
On 23 stumps 20 percent of the roots were burned out.
Average of 196 stumps 61 percent of the roots were burned out.

COST OF STUMP BURNING, TRIAL NO. 1, JEFFERSON, 1915
(196 stumps—Average diameter 39 inches)

Operation	No. of days	Cost	No. of stumps per day	Cost per stump
Cost of banking (labor at $1.50 per day)	18	$ 27.00	10	$0.14
Cost of burning (labor at $1.50 per day)	65	97.50	3	.50
Cost of banking and burning (labor at $1.50 per day)	83	124.50	2	.64
Cost of removing unburned roots (labor at $1.50 per day	133	199.50	1½	1.01
Total labor cost, ready for plow (labor at $1.50 per day)	216	324.00	....	1.65
Interest and depreciation on burner equipment complete	......	7.00	....	.04
Two boxes of powder, caps and fuse	......	16.00	....	.08
Total cost, ready for plow (labor at $1.50 per day)		**$347.00**		**$1.77**
Total cost with labor at $2.00 per day		455.00		2.30
Number of stumps per acre, 15.				
Cost per acre @ $2.00 per stump, $30.00.				
Market value per acre of land cleared, $90.00.				
Percentage of roots destroyed, 61 percent.				

The prevailing wages for ordinary farm labor for winter season work were at that time $1.50 per day, but the cost is also given with wages at $2.00 per day for the purpose of comparison. The farmer who would always have at hand work that could be done in spare time, not readily otherwise employed, returning a compensation of $1.50 per day, would in normal times have no cause for complaint, particularly when the work brought a direct increase in the value of his land and production.

The cost of removing the unburned roots was let by contract, but the actual time used is shown in the tabulation. This work was all done by hand with ax and shovel, fire, and a little powder. Its cost could have been greatly reduced by use of a team and block and line.

No trial was made of the cost of clearing this land by ordinary means since extensive data on this were already available. Although the tops of these stumps were damaged, the roots were perfectly sound. To have blown them out with powder would have required an average of at least 25 sticks per stump, or a cost for powder alone considerably in excess of doing the work complete with the burner. The powder cost ($2.50 per stump for powder, caps, and fuse) added to the labor of blasting, gathering up, piling, and burning the fragments, removing the remaining roots, and filling the holes, would have brought the total cost to double that of stump burning.

Cost of Burner Equipment. If the burner equipment was used steadily during the burning season of the year, approximately eight months, each unit should be able to cover at least 200 stumps. On this basis for a year's work our experience has shown the following consumption or depreciation of equipment.

COST PER STUMP FOR USE OF EQUIPMENT

(200 stumps burned per unit per year)

Stove-pipe, five joints per unit consumed	$1.00
Draft pipe, four feet per unit burned away	1.00
Depreciation, 20 percent on furnace and two hoods, value $20	4.00
Interest at 5 percent on total equipment per unit, value $30	1.50
Total for 200 stumps	$7.50
Cost of equipment per stump, $.037.	

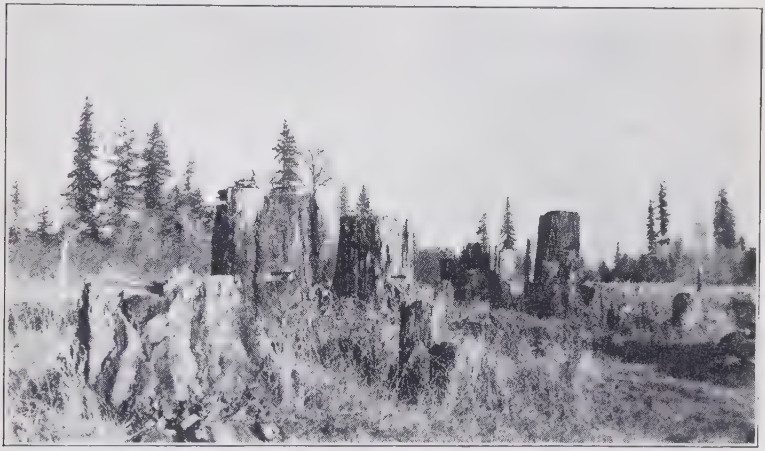

Fig. 28. View of part of stump patch, trial No. 2. Only three roots were left to remove after burning was completed.

Trial No. 2, Crabtree, 1916

In this trial conducted during November and December, 1916, the costs were obtained on the removal of 97 Douglas fir stumps ranging from two feet to eight feet in diameter with an average of 42 inches (Fig. 28).

The soil was a brown loam of good quality and quite satisfactory for banking, except for a period of four days during the trial when the surface soil was frozen. The stumps had been cut from ten to fifteen years and were in average good condition for burning. Our knowledge of how to use the burner had been greatly developed by the mistakes of the first trial.

COST OF STUMP BURNING, TRIAL NO. 2, CRABTREE, 1916

(97 stumps—Average diameter 42 inches)

Operation	No. of days	Cost	No. of stumps per day	Cost per stump
Labor of banking and burning complete (labor at $1.50 per day)	32	$48.00	3	$0.50
Cost of removing unburned roots	1	1.50		.02
Interest and depreciation on burner equipment		3.88		.04
Total cost, ready for plow (labor at $1.50 per day)		$53.38		$0.56
Total cost, with labor at $2.00 per day		69.88		.72

Number of stumps per acre, 30.
Cost per acre @ $0.60 per stump, $18.00.
Market value per acre of land cleared $110.00.
Percentage of roots destroyed, 99 percent.

	Average	Range
Furnace on stump	Average 27.7 hrs.	Range 16 to 50 hrs.
Hood on stump	Average 32.7 hrs.	Range 16 to 50 hrs.
Time required for stump to burn off	Average 4.2 days	Range 2 to 7 days

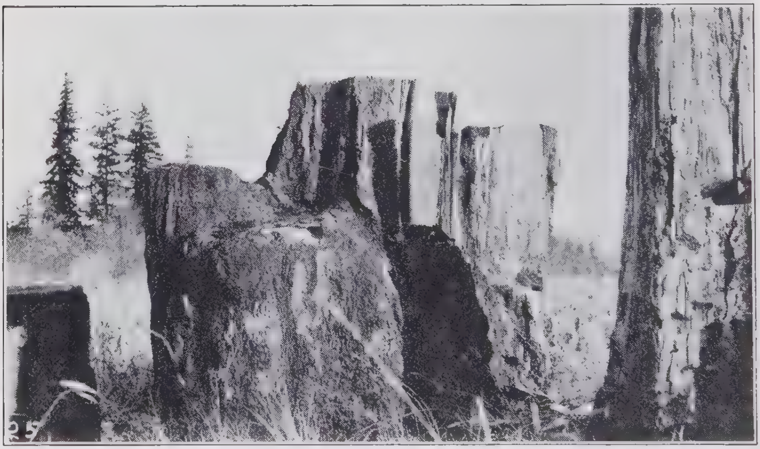

Fig. 29. A big fellow (over 8 feet in diameter) in trial No. 2. Eight to ten dollars' worth of powder would still have left much work to do to finish for the plow.

The hood, the excessive use of which in the first trial proved a mistake, in this trial was used for much less time per stump, and this fact is believed to account in a considerable degree for the excellent success in burning out the roots.

The cost of clearing this land with powder would have been somewhat higher than for the land in trial No. 1, as the stumps were sounder and heavier. It is believed the minimum average requirement would have been 30 sticks of powder or $3.00 per stump for powder fuse and caps alone.

Except that the soil on the average stump land is somewhat heavier, this patch of stumps was typical of the majority of our big stump lands on thousands of acres throughout Western Oregon. It is true that one might seldom get so high a degree of success in destroying all of the roots as in this particular instance, but any method that will get 80 to 90 percent of the main roots above plow depth is satisfactory. In this trial, after the burner work was completed, only three main lateral roots were struck in plowing the ground.

Trial No. 3, Brewster, 1918

This trial was conducted during November and December of 1918, a detailed cost and time study being made of 100 Douglas fir stumps ranging from 2 feet to 7 feet in diameter with an average diameter of 35 inches.

The conditions in this trial were very unfavorable for the most effective use of the burner method, but the trial was undertaken with a full knowledge of this fact, in order to determine as carefully as possible what might be considered a maximum cost under rather extreme conditions where the proper use of the method was pretty well understood.

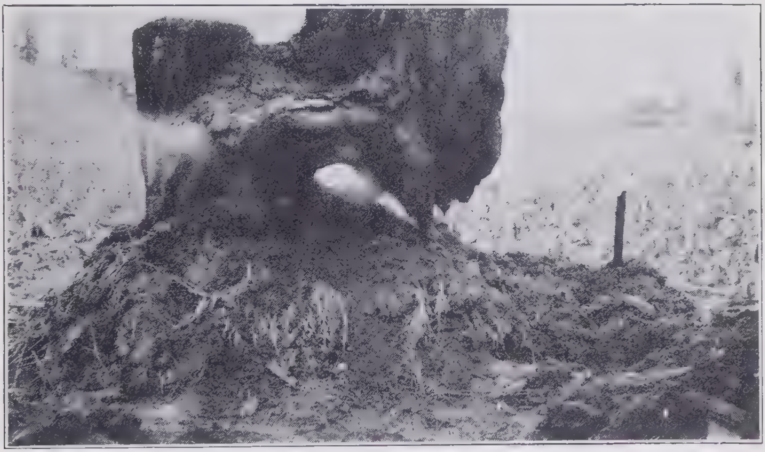

Fig. 30. Same stump as in Fig. 29. The last stub nearly burned off. Stake shows other edge. Not a root left when complete. Cost about $1.00.

These stumps stood on a piece of first bottom on the Santiam river on a sandy loam soil underlaid at varying depths, but usually somewhat shallowly, with gravel, and with a high water table through the summer months.

The stumps ran in age from three to twenty years and as a whole were quite unfavorable specimens for burner work. A careful inspection of them showed that 40 percent had loose bark and some rotted sapwood to be removed; 32 percent were rather too green for satisfactory burning; 73 percent were "doty;" 66 percent were pitchy, making them burn somewhat more slowly and less surely; 98 percent were deep-rooted, connecting the stump with the water table during the summer and thus causing a large percentage of the stumps to be either sour or wet and the roots almost universally wet. In addition the weather was very wet and tended to slow up the work a good deal.

COST OF STUMP BURNING, TRIAL NO. 3, BREWSTER, 1918
(100 stumps—Average diameter 35 inches)

Operation	Man hours	Percent of total	Total cost	Cost per stump
		%		
Preparing and banking (labor at $1.50 per day)	213.5	35	$32.03	$0.32
Tending furnace	217.5	36	32.62	.33
Tending char	29.5	5	4.43	.04
Rebuilding fires	25.5	4	3.82	.04
Other work	111.0	19	16.65	.17
Total for banking and burning	597.0	100	$89.55	$0.90
Removing unburned roots	176.0		26.40	.26
Leveling ground for plowing	29.0		4.35	.06
Leveling ground for plowing (14 horse hours)	....		1.40	
Total labor cost, ready for plowing	802		$121.70	$1.22
Powder, fuse and caps for removing roots			16.00	.16
Interest and depreciation on equipment			4.00	.04
Total cost, ready for the plow (labor at $1.50 per day)			**$141.70**	**$1.42**
Total cost, with labor at $2.00 per day			181.80	1.82

Number of stumps per acre, 18.
Cost per acre at $1.50 per stump, $27.00.
Market value per acre of land cleared, $100.00.
Percentage of roots destroyed, 86 percent.

AVERAGE TIME REQUIREMENTS, BREWSTER TRIAL
(100 stumps)

	Range	Ave. per stump
Diameter of stumps	2 to 7 ft.	34.9 in.
Height of stumps	2½ to 9 ft.	49.1 in.
Furnace on stump	11 to 53 hrs.	27.3 hrs.
Total number of stokings of furnace	2 to 8	5.0
Hood on stump	11 to 73 hrs.	39.3 hrs.
Time required for stump to burn off	2 to 9 days	4.0 days
Preparing and banking stumps		2.1 hrs.
Tending furnace		2.2 hrs.
Tending char-pitting end of process		.3 hrs.
Miscellaneous work in burning		1.3 hrs.
Total work of banking and burning		6.0 hrs.
Finishing up after burning ready for plow		2.0 hrs.
Total time, ready for plow		8.0 hrs.
Percentage of stump tops that fell off to one side of pit		9%
Percentage of stumps, all roots burned out		61%
Percentage of stumps, roots partly burned out		39%
Percentage of main laterals burned out, all stumps		86%

RATE OF BURNING AS AFFECTED BY CONDITION OF STUMPS
(Brewster trial, 100 stumps)

Condition of stump	Average diameter	Average time furnace on	Av'ge burned per hour	Average time hood on	Average time stump burned off
	in.	hrs.	in.	hrs.	days
Pitchy	37	38	.97	50	4.5
Non-pitchy	32	28	1.14	34	4.6
Sour	37	33	1.12	47	4.8
Cured	34	31	1.09	45	4.3
Young	39	38	1.02	57	5.3
Old	33	30	1.10	39	4.2
"Doty"	35	34	1.02	44	4.6
Sound	38	30	1.26	51	4.6

The rate of burning varies according to the condition of the stump. Sound stumps are shown to burn 23 percent faster than "doty" stumps, and non-pitchy 17 percent faster than pitchy. Frequently a very pitchy stump will take twice as long to burn through. The rate was low on all the stumps in this trial. In a number of other tests where conditions were more favorable 2 inches per hour was a fairly common rate, and 3 inches per hour was sometimes reached in Douglas fir. In spruce, particularly, and in pine the rate is faster.

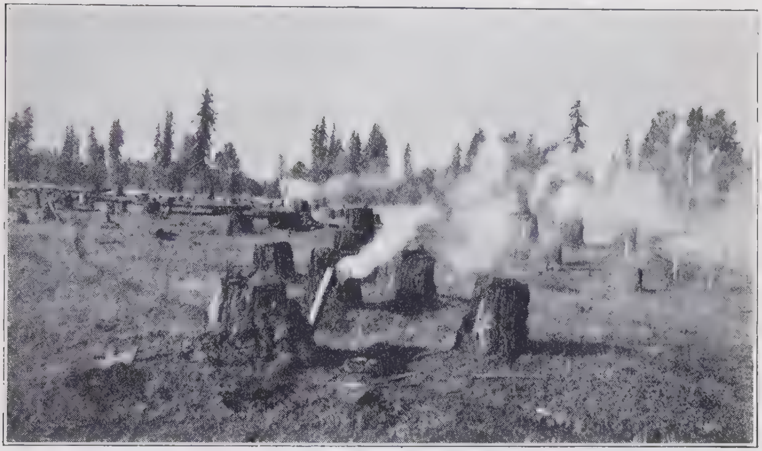

Fig. 31. View of burners at work, trial No. 3. Very unfavorable conditions for burner work.

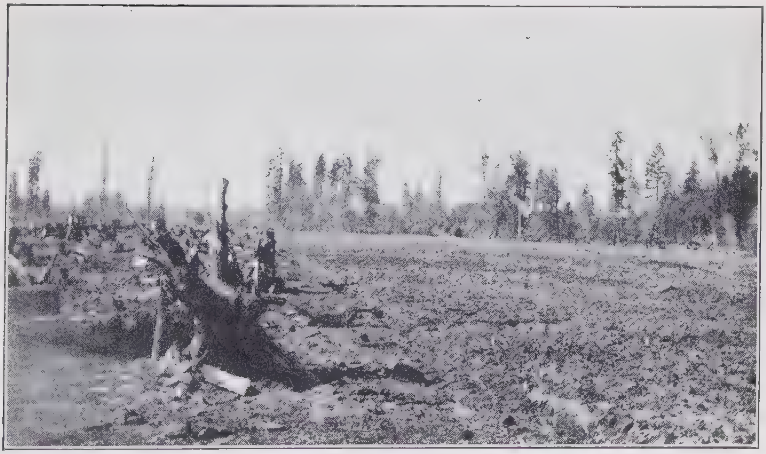

Fig. 32. Same ground plowed and ready for crop. Total cost of clearing $25.00 per acre.

Cost With Powder. In order to get at the cost of clearing this land by ordinary means, 10 stumps scattered through the field where the stump burning was done were selected as typical and representative in every way of those burned. Expert powder men were selected to do the work and they did it well. The cost is shown below.

COST OF BLASTING OUT STUMPS, BREWSTER TRIAL

	Range	Ave.	Man. hrs.	Total cost	Cost per stump
	in.	in.			
Diameter of stumps	23 to 61	35.8	....	....	......
Height of stumps	39 to 90	51.0	....	....	......
Number of sticks of powder	15 to 80	26.5	....	$26.50*	$2.65
Labor of blasting at 30c per hr.			18	5.40	.54
Taking out roots and filling holes @ 15c per hour			45	6.75	.68
Taking out roots and filling holes, 30 horse hours @ 7½c per hour			....	2.25	.22
Piling and burning fragments			10	1.50	.15
Total cost, ready for plow				**$42.40**	**$4.24**

*80 sticks of powder per 50 lb. box at $8.00 per box, including caps and fuse.

Other Tests. In addition to the three cost trials reported above, 15 other field tests of the method have been made, all under the supervision of the writer with the exception of the one in Lincoln county, as follows: Benton county, 2; Linn county, 3; Lincoln county, 1; Clackamas county, 1; Washington county, 1; Columbia county, 3; Clatsop county, 1; Multnomah county, 1; Lane county, 2.

In these tests Douglas fir, western yellow pine, spruce, and oak were burned; the diameters of the stumps ranged from 1½ feet to 12 feet; age 5 years to 35 years; soil, fine sandy loam, loam, silt loam, and clay loam, on river bottom, tideland, valley floor, and red upland.

In every case the burner demonstrated its economy and efficiency in burning out stumps and roots following the methods described herein. Repeatedly it was shown that on the average Douglas fir stump, one man with 4 burner units could average 3 stumps per day, and this is a pretty good rough measure of cost. Only on spruce or under very unfavorable conditions with fir would this average not hold true. On pine and oak the work was faster, as the diameters were smaller, less banking was required, the furnace required less time, and the hood did not need to be kept on nearly so long as in case of fir. With 5 burner units the writer believes a good worker conversant with the method, working on the average fir stump under reasonably favorable conditions, might be able to average 4 stumps per day.

SUMMARY OF COST DATA

	Trial No. 1	Trial No. 2	Trial No. 3
Number of stumps	196	97	100
Range in diameter, inches	20-66	24-96	24-84
Average diameter, inches	39	42	35
Condition of stumps and soil	Very bad	Good	Bad
Average percentage of roots burned out	61	99	86
Labor cost per stump of banking and burning	.64	.50	.90
Labor cost per stump of removing unburned roots	1.01	.02	.32
Powder cost per stump of removing unburned roots	.08	.00	.16
Cost per stump for use of equipment	.04	.04	.04
Total cost per stump, ready for plowing	1.77	.56	1.42
Total cost with labor at $2.00 per day	2.30	.72	1.82
Estimated cost of removing these stumps without burner, for powder only	2.50	3.00	2.65
Actual total cost with powder, complete for plowing			4.25
Approximate number of stumps per acre	15	30	18
Cost per acre of clearing with stump burner	26.55	16.80	25.56
Estimated market value per acre of land cleared	90.00	110.00	100.00

SUMMARY OF TIME DATA

Average number of hours per stump for furnace		27.7	27.3
Range, hours		16-50	11-53
Average number of hours per stump for hood		32.7	39.3
Range, hours		8-63	11-73
Average number of days for stump to burn off and settle		4.2	4.0
Range, days		2-7	2-9

ADVANTAGES OF THE STUMP BURNER METHOD

Outstanding features of this new method may be briefly summarized as follows:

Lessened Cost. It reduces cost of clearing big stump land 50 percent or more as compared with present methods, making it possible to clear logged-off land at a cost at which it can compete in the open market with similar lands already cleared. With labor at 20c an hour, the average big stump costs from $0.75 to $2.00 to complete the job ready for the plow.

Easier Work. It greatly reduces the laborious character of land-clearing work. Land clearing with present methods is probably the most back-breaking, heart-breaking, and hence unattractive work that the man on the land undertakes. The hardest work in this method is shoveling the bank (a short, light task compared with the old grub hoe work), and banking usually requires less than one-third of the total labor expended in the stump burning process.

Less Work. It leaves the ground in very satisfactory condition for plowing and cropping. There are no holes to fill, no stumps to pile and burn. The earth bank and ashes fill the stump cavity, leaving the ground nearly level. The stump and roots are burned in place.

No Soil Damage. It does not injure the soil, but improves its condition and crop productive power.

Uses Cheaper Labor. It is especially well adapted to Pacific Slope seasons. The burner can be used as soon as the soil gets wet in October, throughout the winter, and until the soil gets too dry to bank in June. During this period hired labor is cheapest and the farmer himself has most time available for land-clearing work.

Fits the Settler's Labor Program. The burner fits in with farm and other work. A battery of four burners will keep one man busy full time, but two burners may be used if desired so that only a few hours daily or at odd times may be expended, thus fitting in with winter chores and winter farm work.

Practical. It is a simple and natural process without complexities, easily learned and applied, requiring only a little patience and study to master.

No Expensive Equipment. It requires only a simple, inexpensive appliance that may be used hundreds of times and then sold to a neighbor at little less than original cost.

Adds Interest. The use of fire is interesting to most men. The burner puts fire and wits against the stump instead of costly powder, tedious pulling, and sweat and endurance with a grub hoe.

Reduces Cash Outlay. The usual method requires heavy cash outlay for purchase of powder, where the burner method requires only a small investment and spare-time labor.

PART II. PRELIMINARY STEPS IN LAND CLEARING
OTHER METHODS OF BURNING STUMPS

Value of the Land. Obviously prior to any clearing most careful consideration must be given, first, to the probable value of the land when cleared—its possible and most profitable use as affected by its location with reference to market, community advantages, etc.—its productive capacity as affected by soil, elevation, topography, climatic conditions, etc. A volume might be written on trees, brush, and other plants as indicators of soil fertility. Large trees do not always indicate a fertile soil. Usually density or heaviness of growth is a better guide than size of individuals, or than species, although species tell much. The best guide is the county agent, or agricultural college authorities. Second, must be considered the cost of clearing as affected by many different conditions and comparison of cost with market value of similar land already cleared. It is by no means wise to buy stump land just because it is cheap unless one is sure that, including the cost of clearing, in labor, time, and cash outlay, its total cost will be less than that of similar land already cleared.

Pasture and Forest Land. Thousands of acres of rolling land west of the Cascades too steep for profitable tillage but contiguous to good farm land may be profitably reclaimed for pasture, yet do not justify the removal of the stumps. Surface clearing (that is, slashing and burning of brush, making up of the marketable wood, and piling and burning of the dead and "down" stuff), followed by a seeding to grass, fencing into sections for rotation of pasture, and "stocking up," would convert this land into profitable pastures.

A still larger area of hill and mountain land too rough or isolated for profitable grazing should go back into timber production. It is the hope and dream of every forward-looking citizen that, with state and private owners cooperating, a feasible policy of practical reforestation will be worked out and put into effect before this natural resource of the state is further depleted.

Aging of Stumps. There can be no question that the aging of the stump has a vital relation to economy of clearing. Green stumps of any kind are not burned successfully with the stump burner, nor can they be removed by ordinary means (powder and puller) without greatly increasing cost.

Under the climatic conditions west of the Cascades nearly complete rotting of hardwood tops and roots, if sprouting has been prevented, usually occurs in six to ten years, while in three to four years the smaller roots have rotted sufficiently to reduce greatly the cost of pulling and removal of earth from the roots, yet the tops are still sound for the choker. At two to three years of age the large hardwood stumps are sufficiently cured for satisfactory burning.

In conifers (firs, spruce, etc.) the stump is sufficiently cured to burn well four to five years after cutting, and from five to fifteen is usually in ideal condition to burn and from five to ten years of age in best condition for powder and pullers. Beyond ten years little is gained for use of powder and puller as the smaller stump tops are getting unsound for the choker and in the larger stumps the main roots still persist, little affected sometimes for a period of thirty or forty years, or longer.

Slashing and Burning. Slashing the stump land clean is a necessary preliminary to removing the stumps. If slashing is done immediately after logging a great deal of work is saved. Usually before the clearing stage is reached plenty of small growth has developed. If this is heavy it should be slashed to lie all in the same direction in order to maintain the best possible contact for firing. If this surface growth is thin it should be piled in windrows for good contact, the windrows being made parallel with the prevailing wind. The brush should be thrown in from the margin to leave a clean fire lane for necessary fire protection.

For hardwoods and other deciduous growth it is best to slash in full leaf, in spring or early summer, in order to reduce sprouting later. Hardwoods should be cut two to three feet from the ground to reduce root sprouting and also to facilitate pulling. Where the stump burner is to be used the large snags and dead trees need not be cut off unless it is necessary to reduce danger of fire spreading from the burning tops. Large logs or stumps rotted clear through, should be broken up so that they will dry out during the summer prior to setting the slashing afire. Sometimes it is possible to pile small "down" stuff so that it will have good contact and burn out when the slashing is fired.

It is decidedly better not to pile stuff over the large stumps, as they are more easily handled afterwards with the burner or with powder, if not partly burned away previously, but left with bark and bole intact. Nothing puts a stump in worse condition to handle than surface fires that burn away the larger portion of the top, making it necessary to remove each root individually.

Very large logs may be burned in place by splitting them horizontally with powder and piling small stuff at intervals to start the log afire. Splitting a large log for burning in place is easily done by boring a hole horizontally in line with the center of the log every 8 or 10 feet and charging with one-half to one stick of stumping powder, or better yet using a splitting gun and one-quarter to half a pound of black powder. The horizontal splitting of the log makes a chimney for the fire so that the log will burn from the inside out and thus keep afire and burn out quite completely.

The cleanest burn is usually obtained by firing in September. A fire permit should be secured and every precaution taken to avoid fire spreading to adjoining land.

Some men prefer to set fire to the slashing on a rather windy day, but where the slashing is heavy and thoroughly dried out, a quiet day, preferably very early in the morning or at night when there is the least wind, is a safer time to start. With no wind fire may be set on two sides. Wind not only increases the danger of the fire spreading but often prevents a clean burn unless the slashing is thin and has not been windrowed. On heavier slashings it is usually better, if there is any wind, to burn against the wind to secure the cleanest burn and greatest safety.

For the benefit of our future forests it is well to remember that land that is to be reforested is best burned in the spring directly after logging to avoid destroying the seeds from which the new forest comes.

Seeding. On land with green stumps or any other land that is not to be cleared immediately, grass seed should be sown in the ashes as soon as they are cool and before the first rains. Ashes make an ideal seed bed for grass as the first rain covers the seeds. An excellent mixture for Western Oregon is 10 pounds of perennial rye grass, 5 pounds of orchard grass, and ½ pound of white clover seed per acre. Sometimes a little timothy and alsike seed is added to this mixture. A chest or tube seeder facilitates uniform spreading of the seeds.

It is highly important not to pasture such seedings the first year but let the grass get well rooted and go to seed. If the land is pastured the first year stock should be kept off at least during the spring until the grass roots get well set.

Following a very heavy burn with plenty of ashes it is possible to get good results on the better types of land by broadcasting vetch and wheat, particularly if the land is soon to be cleared and grass not desired. Such seeding can be pastured with cattle, hogs, or sheep.

On land with little or no brush, a heavy growth of fern burned in September and seeded in the light ash will frequently give a good stand of grass. On stump lands without either brush or fern ash where the surface has been sufficiently cleared it is sometimes possible to disk or spring-tooth sufficiently to make a fairly satisfactory seed bed for sowing grass in the fall.

On seedlings where there is considerable deciduous and hardwood growth the pasture is first used by cattle and goats and then by sheep and goats. On logged-off land where there is little deciduous growth the pasture is used first by cattle, then sheep, and then by goats. Grazing is continued for three to five years, and the land is then ready for clearing.

Goating. A volume might be written on this subject, but a few suggestions must suffice. On newly slashed hardwood land nothing equals the goat for quickly destroying sprouts and thus the vitality of the stump. It is important to kill such growth immediately or in a few years the land is harder to clear than in the beginning.

If oak is cut two to three feet above the ground the sprouts are more likely to start from the stump instead of from the roots, and stump sprouts are much more easily destroyed than root sprouts.

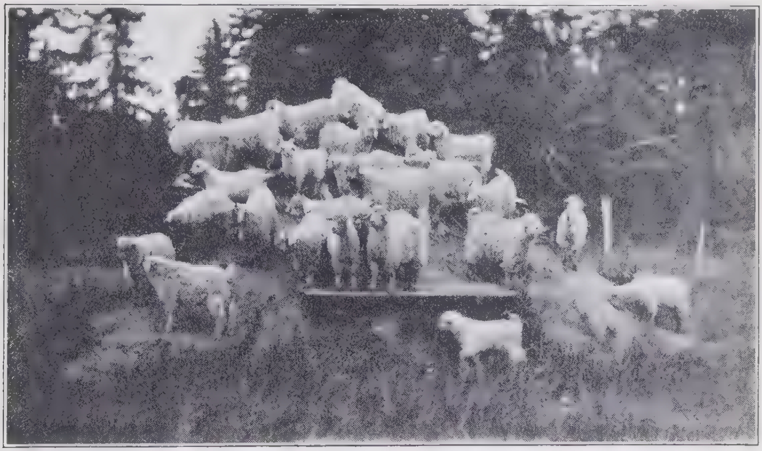

Fig. 33. An indispensable and efficient aid for destroying brush growth. Some of Mr. Zysset's pure breds.

It is often claimed that goats will not destroy certain kinds of brush such as willows, hazel brush, dogwood, etc. It is true goats will not destroy brush that is too high for them to reach. Tall brush should be slashed ahead of the goats to a height they can reach. It is also true that goats have preferences in brush, and if there are not enough goats for the acreage they will destroy only that which they like best. Goats also like grass and if there is plenty of grass they will not do much with the brush. Hardwood land to be goated should either not be seeded or the grass pastured off first with cattle or sheep. Poison-oak and madrone are generally considered to be the brush that goats like least. Goats, if properly handled, will destroy nearly all other deciduous growth in two years.

An important requirement for success is to use enough goats. From four to five goats per acre on fairly heavy growth are not too many. On large areas it is also important to fence the land in sections, concentrating the goats on each section for a short time until browsed clean, then moving them to a new section and then back again to the first section. In this way the browse is kept fresh for the goats and thus more quickly destroyed. Where properly handled, the writer has seen goats do almost perfect work repeatedly.

Surface Clearing. This term may be applied to clearing away the surface debris either before or after the slashing and burning is done. It may be done partly prior to burning and the remainder afterward. If in the burner method only two burner units are used, the time not used in tending the burners may be expended in surface clearing. The chief operation in surface clearing is the piling and burning of logs.

Piling. Some sawing of long sticks of small diameter is necessary so that they may be handled. Piling in small piles fairly high with sticks lying parallel, six to ten logs, is cheaper and better than piling in large heaps with the gin pole. Small piles damage the soil much less in burning and can be more easily tended when they "cup out." Logs and stumps should always be piled separately to get the best results. On small stump land handled with the puller the cost of disposing of the stumps is a considerable item. The Conrath piler much used in Wisconsin is one of the best devices for piling stumps.

In piling small logs that cannot be readily handled with the peavy, a chain or half-inch wire cable 20 to 30 feet long and two timber skids may be used with satisfaction. The pile is built by passing the cable end under the log to be moved and hooking it into the log that is the center piece of the pile. With this "rolling hitch" the logs are rolled up until the base, consisting of four or five logs lying parallel and close together, is formed. On the five base logs four more logs are piled, then three, then two, and then one on top, the skids being used to roll the logs up on the pile as it grows higher. Two men and a team can often surface clear as much as an acre a day of fairly heavy stuff this way.

Very large logs may best be burned in place as already described, starting the splitting and fire at one end.

PULLING STUMPS

A stump puller equipment of some sort is an essential part of the work of clearing land, no matter what other methods may be used in conjunction with it. Where the stump burner is used for the big stumps, a puller device of some kind, supplemented with small amounts of powder, is used on the stumps less than two feet in diameter. Discussion of methods of pulling stumps can not be given here, and only a brief statement can be made regarding the various common pulling devices. Our experience has shown that the smaller stumps can be pulled efficiently and economically by any of several different devices supplemented with a limited amount of powder. For average conditions and means, perhaps the best devices are logger's hooks, root plow and block and line or the two-horse capstan puller or the recently invented engine-operated capstan puller.

The Donkey Engine. A great deal of land has been cleared in the Northwest with the donkey engine (combined with powder, of course). While this method gets fairly rapid action, material objections have been found to its use.

First, it requires a capital investment beyond the reach of the men who do most of our land clearing. A good donkey outfit costs $4,000 or better, though sometimes a good second-hand gear can be had for less.

Second, it does not reduce the cost of clearing sufficiently to be economical; i. e., to clear land at a cost less than the market value of the land when cleared. For this reason, organized community effort with a donkey outfit will not necessarily solve the land-clearing problem.

Third, the operation of such an outfit is by no means simple and requires skilled and experienced labor.

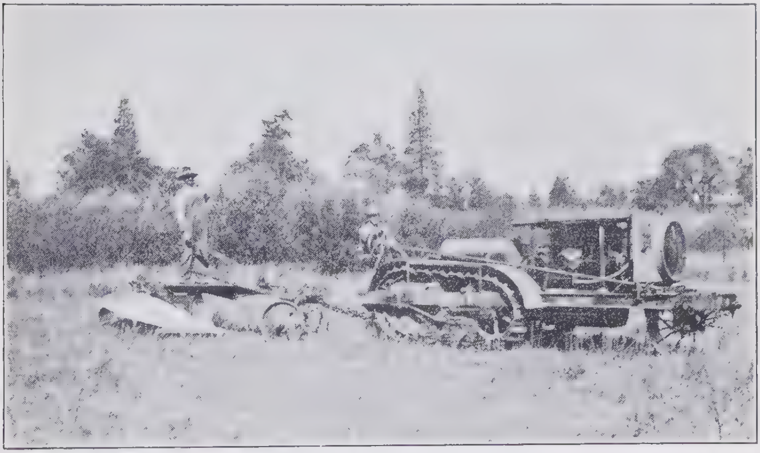

Fig. 34. This heavy outfit plowed out the brush in the background, up to three inches in diameter.

Fourth, this method does not get rid of all of the roots, nor fill the holes, and hence leaves much hand and team work to do.

Fifth, burning of the huge piles of stumps and logs laid up with the donkey outfit damages the soil.

Hand Pullers. The antithesis of the donkey puller, the hand puller, does good work and requires only a small investment, but it is slow and very laborious, in fact a real "man killer."

The Tripod Puller. The tripod puller is a powerful and effective vertical-lift puller fairly satisfactory on light stands and light soils, but slow and cumbersome to set up and move about.

The Farm Tractor. The farm tractor does fairly good work on light stuff, and where the farmer owns one it may be used to advantage, but can not be considered satisfactory equipment for regular land-clearing work. The larger tractors are used successfully for plowing out brush up to 3 inches in diameter, a heavy grub breaker with 24-inch share and high clearance being used (Fig. 34).

Block and Line. One of the best methods for the man of limited means is the block and line. Double- and triple-power pulleys may be used. Powder is a necessary supplement.

The Horse Capstan Puller. This is a standard and efficient pulling equipment. With loggers' hooks, root plow, good take-up device for the cable, good chokers and a power pulley, supplemented with powder (for loosening the stump, shaking off the earth or cracking it), the capstan puller, horse operated, is an efficient and economical method of handling the smaller stumps, although somewhat slow and tedious. In pulling with the capstan, the size of the stump or part pulled should not be larger than a team can handle afterwards in dragging off and piling. Usually a size that can be pulled with a ¾-inch wire cable is about as large as can afterward be handled by the team. A ¾-inch cable with a capstan permits a 20,000-pound pull, and this is about as large as ordinarily should be used.

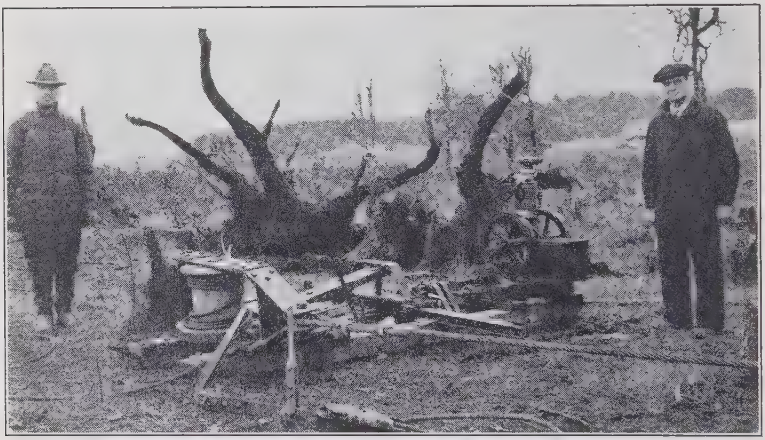

Fig. 35. The gas-engine-operated puller, efficient and labor saving on the smaller stumps.

The Gas Engine Capstan Puller. This device in its improved form, invented by an Oregon man, has been used extensively in our experiment station work.

An ordinary 6-horse-power stationary farm engine is connected by gears to a capstan, all being mounted on skids so that the puller may be easily moved about. The puller operates at two speeds for light and heavy pulls. It does the work somewhat more rapidly and economically than the horse-operated capstan, with somewhat less danger of accident, and is decidedly less tedious (Fig. 35).

STUMPING POWDER

Powder is a most valuable and indispensable adjunct and necessity in all land-clearing work as a supplement to the puller in handling stumps up to 24 inches in diameter or thereabouts. Its most advantageous use is in loosening the stump and shaking off the earth, splitting stumps for the puller, removing stubs or heavy fragments of roots, splitting logs, etc. Almost universal experience throughout the country has shown that the 20 percent powder is the best strength, except perhaps on very sandy or gravelly land. Powder is not chemically injurious to the soil, but frequently throws a good deal of undesirable subsoil on to the surface.

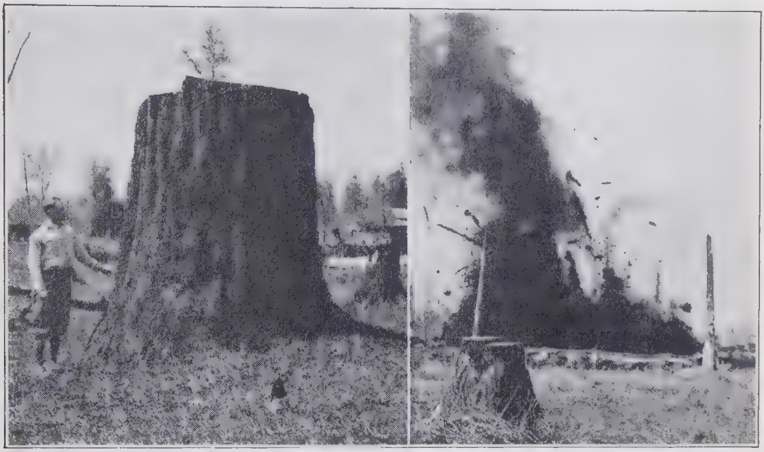

Fig. 36. A big fellow and a box of powder in action in trial No. 3.

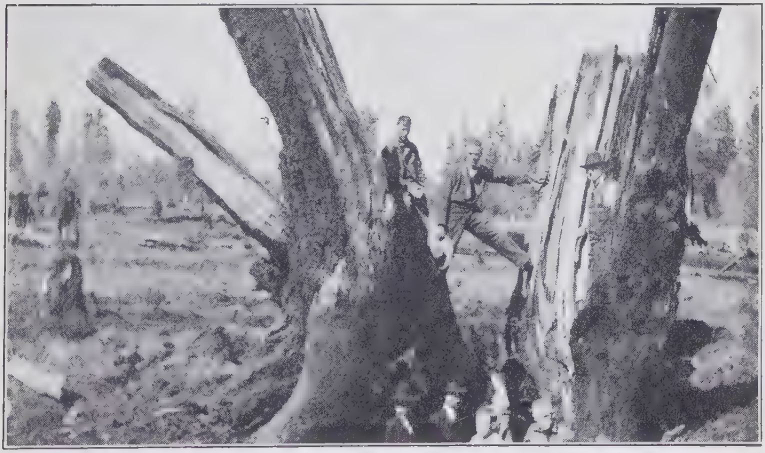

Fig. 37. Same stump as in Fig. 36. Eight dollars' worth of powder used and plenty of action still needed.

Powder is not dangerous if its use is understood. Where stumps are thick and divided charges may be used advantageously, however, the employment of an electric firing device reduces the amount of powder and labor required, somewhat decreases the total cost of clearing, and greatly increases safety. Nine out of ten powder accidents in land clearing are due to the use of cap and fuse.

No accurate rule can be stated as to the amount of powder to use that will fit the needs of any given case. Two general rules sometimes given may be of some guidance to the beginner.

(1) The number of *pounds* of powder required to shoot a stump clear of the ground is the same as the square of the diameter of the stump in *feet*, (Ex. 2 ft. diameter—4 pounds of powder, 6 ft—36 pounds, etc.)

(2) The number of *sticks* of powder required to blow large stumps clear of the ground (under most conditions in the Northwest) is the same as the diameter of the stump in *inches*.

Neither of these rules is satisfactory for small stumps.

(3) For cracking stumps ready for the puller use ⅓ to ½ the amounts specified above.

THE USE OF CHEMICALS

Inquiry regarding the use of chemicals in destroying stumps is so frequent, and hope that an easy way may be found in this direction is so common, that it may be well to state here that no method of destroying or even aiding in the destruction of stumps through the use of chemicals of any kind has yet been found. The mere physical mass of the stump and its roots is so great that the cost of any sufficiently effective agent would probably be too great, entirely aside from the possible injurious effect on the soil.

The most common inquiry is regarding the use of saltpeter, saltpeter and kerosene, etc. This has been tried repeatedly and found of no value. Some, no doubt, have been misled in this because a stump already in excellent condition to burn without treatment of any kind, has been charged with saltpeter and then burned successfully.

The use of stumps for by-products through distillation has been studied extensively and is still under investigation. Something helpful in reducing the cost of land-clearing may eventually result, but under Northwest conditions the procedure has not been found feasible as yet.

THE CHAR-PITTING METHOD

As frequent inquiries are received regarding the old char-pitting process, a brief statement regarding the procedure followed and a comparison with the stump-burner method seems desirable here.

Since the stump-burner method is a modified char-pitting process all that has been stated regarding kinds and conditions of stumps, character of soil, procedure in banking, etc., applies to the old char-pitting method as well.

Procedure. In regular char-pitting the usual procedure is to remove the bark around the base of the stump about one foot in height, then encircle the stump with several layers of kindling, consisting of sixteen-inch wood, split to stove-wood size, and mixed with some bark. This kindling is laid against the stump, upright but overlapping and slanting in the direction the fire is to run, so that the fire will be led from the starting point as easily and as rapidly as possible around the stump (Figs. 38 and 39). Two layers of the kindling wood, or somewhat less, are used. The wood is then banked over with earth, the bank being kept

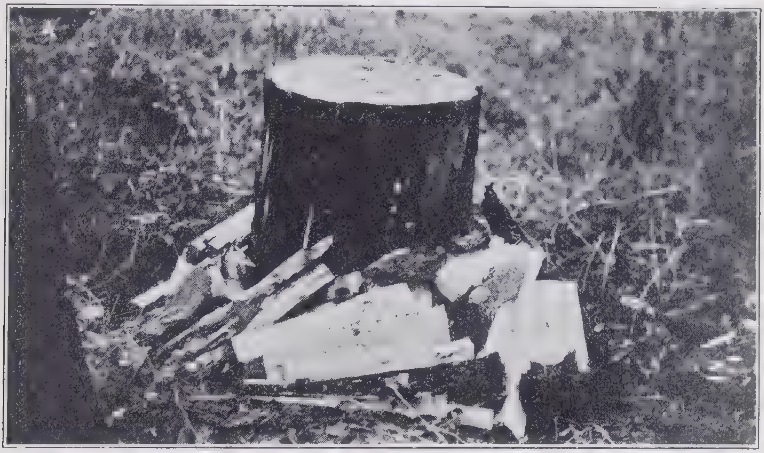

Fig. 38. Showing placing of fire wood in the regular char-pitting process. Ready to bank.

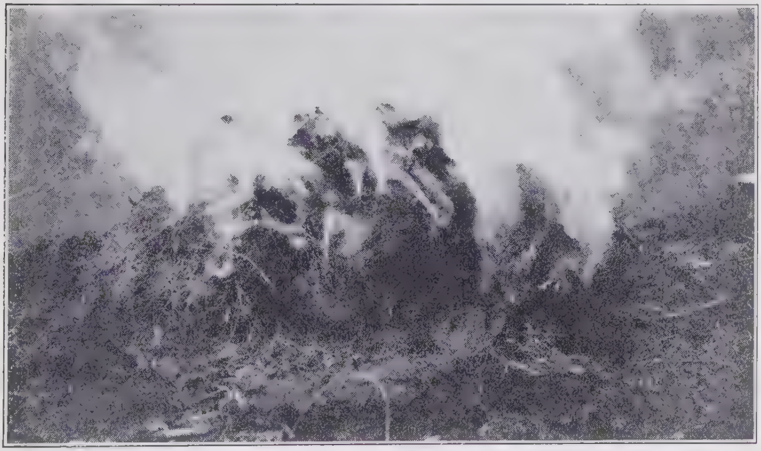

Fig. 39. Banked in and fired. Roots were completely burned out, but the process is not as easy to learn as might appear, nor as efficient as the stump burner.

about four to six inches in thickness, and sealed to the stump at the top following the same procedure in banking as described for the stump-burner method except that the bank is made somewhat less thick and less compact, to permit better ventilation.

An opening about a foot wide is left in the bank in the windward side. Here some pitch wood and fine kindling is used to start the fire. Sometimes in wet weather a handful of ashes saturated with coal oil or fuel oil mixed with sawdust, is used to start the fire. As soon as the fire is started briskly it starts to encircle the kindling under the bank of earth and usually in half an hour or so the opening in the bank where the fire has been kindled may be closed over with a slab of bark and banked in. In this way the stump is slowly set afire on the outside, and thereafter the chief requirement is care to keep the fire banked in. Usually the best results are secured in the summer when the stump and wood are dry, although banking is more difficult at that time.

Another method of char-pitting in many ways preferable to the foregoing, is what may be called side-pitting. Instead of laying kindling and firing all around the stump, a pit is dug at an interval between two main roots, a foot or more below ground level. The bark is cut away at this firing point and fire started in the pit. This is then covered over and maintained until the stump is afire at this point and then the stump is banked in.

Comparison of Char-pitting and Stump-Burner Method. The chief difference between the two methods is: (1) the method of setting fire to the stump, and (2) the character and effectiveness of the fire produced. In these two respects the difference in favor of the stump burner method is so great as to put it in a class by itself.

As has been stated heretofore a very great difficulty in the old char-pitting process was that of learning how to start the fire successfully, causing most beginners to discard the method entirely, and even to the experienced operator always a source of more or less difficulty, especially in wet weather and with wet stumps. With the stump burner method, on the other hand, starting the fire is easy and certain, regardless of the weather or condition of the stump.

The difference in the character of the fire produced by the two methods is almost as pronounced as the difference in the methods of starting the fire. In char-pitting the fire burning from the outside of the stump, burns away the connection between the stump and the roots and between the stump and the bank, at the very outset. Thus some roots are not thoroughly fired and do not burn out, and further the bank is left unsupported by the stump and falls in more readily and increases the difficulty of either producing or maintaining a thorough firing of the stump, and usually cutting off the central fire from the roots. With the stump burner, on the other hand, the heart of the stump is fired first and from this point the fire gradually burns outward to the perimeter of the stump leaving the bank undisturbed until the whole stump sinks in, and maintaining permanent connection between the central fire and the fires proceeding down the roots. The result of this difference in the character of the fire produced is that where char-pitting will burn out fifty percent of the roots, under the same conditions the stump burner will burn out eighty percent or better.

OTHER METHODS OF BURNING STUMPS

Open Burning. Occasionally a stump thoroughly dry, pitchy and in ideal condition to burn may be burned out fairly well or even completely by piling waste wood on it and firing. Very seldom, however, will all of the roots burn out, and only rarely are stumps found that will burn out any portion of the roots this way. Open burning, therefore, that is, burning without banking, however the fire may be started, fails to give satisfaction in burning out roots.

Splitting and Burning. Enough powder is placed under the stump to crack it and make a cavity underneath, which is filled with wood and fired. This method is better than the preceding method but also fails to burn out the roots satisfactorily.

Trenching and Cracking. This method is used with fair success on pine. A narrow trench, eight or ten inches deep, is dug around the stump, and from the bottom of the trench a hole is bored downward to the heart of the stump and charged with a stick of powder, which cracks the stump. A fire is then started with kindling in the trench. One operator was observed using this method, who after the fire was well started covered the whole stump with wet, rotted straw, which tended to confine the fire and thus burn out the roots more effectively.

One-Hole and Two-Hole Methods. This method is used chiefly on pine. A hole about thirty inches deep is dug on one side of the stump, the earth being cleaned away from the tap root, and in this hole a fire is set. Sometimes a second hole is dug on the opposite side and a connection between the two punched through, fire being set in both holes.

Boring and Burning. A number of boring and burning methods have been tested and used more or less. The boring is done by means of hand augers, augers mounted on a frame work and operated by cranks, augers mounted and operated by gas engines, and double augers mounted to bore vertically and horizontally at the same time. One method used with considerable success on pine is to dig a pit twenty inches in depth on one side of the stump, then from a point slightly below ground level on the opposite side of the stump bore a hole slanting down into the bottom of the pit, where a fire is then started.

Under this head are found also many variations of what is sometimes called the intersecting hole method. One of the most common and best of these is to bore a slanting 1¾-inch hole into the stump about 18 inches, starting about 18 inches below ground level. Then a vent hole from ground level and at right angles is bored to meet the inner end of the first hole. The first hole is then fired with a hot iron, and when well afire a 1¼-inch pipe is inserted and used as a draft pipe. In all of these intersecting hole methods, however, setting a stump afire is by no means easy, particularly where the stump is soaked up and the weather wet. Furthermore, as in all burning methods, unless the stump is banked in, only a percentage of the roots will be burned out.

Decapitation Method. This is one of the best of the burning methods and has been given considerable study by the Idaho Experiment Station. A stump is sawed off as close to ground level as possible. The upper part of the stump is then lifted up enough to insert stones around the edge so that there is a distance of two to four inches between the base and upper part of the stump. Fire is then started in this space, usually in the summer. The two burning faces radiate their heat against each other and thus aid in burning out the root crown. The stump may be banked in and thus greatly increase the effectiveness in burning out the roots.

Air Blast Method. An engine-operated fan sending an air blast through piping to the stump to force the fire down into the stump and roots has been extensively tested. It has not been found to burn out the roots very satisfactorily, and a considerable expense for the equipment and its operation and the attention required have made the method impracticable.

Hood Burning. It is claimed that something more than twenty patents for different sorts of devices for hooding and burning stumps have been issued. Usually the idea is to cover the stump completely with a hood made of sheet-iron or other material. The stump being fired, the draft and chimney of the hood permit it to be burned out pretty completely, if it is dry and in fairly good condition. The difficulty in this method is that it does not burn out the roots; furthermore, the destructibility of the hood, the difficulty of moving it and setting it up, the cost of the hood and the number required, the difficulty of covering the larger stumps, and the slowness and labor cost of the whole proceedure make this method impracticable.

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Station Bulletin 196 January, 1923

Oregon Agricultural College

Experiment Station

Department of Animal Husbandry

Finishing Pigs for Market

(Revised Edition)

By

A. W. OLIVER

and

E. L. POTTER

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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SUMMARY TABLE

Ground barley is the principal hog feed for Oregon, and therefore the other feeds are compared with it. Shorts, for example, is given the value of 90, which means that 100 pounds of shorts has the same feeding value as 90 pounds of barley.

GRAIN AND MILL FEEDS

Feed	Relative value	How used. (The relative values given apply only when feeds are used as indicated)
Barley—ground	100	As the chief grain ration
Barley—whole	88	As the chief grain ration
Wheat—ground	100	As the chief grain ration
Wheat—whole	88	As the chief grain ration
Corn—ground	100	As the chief grain ration
Corn—whole	95	As the chief grain ration
Oats—ground	90	Not over 1/3 of grain ration
Oats—whole	....	Not advisable
Middlings	105	For sows and young pigs
Middlings	100	For fattening hogs (not over 1/3 of ration)
Shorts	95	For sows and young pigs
Shorts	90	For older hogs (not over 1/3 of ration)
Mill-run	...	Varies greatly
Bran	75	For maintenance only (contains too much fiber for fattening)
Cocoanut meal	100	Not over 1/4 of the ration

SUPPLEMENTAL FEEDS

Skim milk or buttermilk	33	Not more than 3 lbs. of milk with 1 lb. of grain
Skim milk or buttermilk	12	In unlimited amounts (not advisable)
Tankage (60 percent)	300	5 to 10 percent to balance the ration
Oil meal	150	10 to 20 percent to balance the ration
Soy bean meal	190	8 to 15 percent to balance the ration
Cottonseed meal	....	Dangerous for pigs

SUCCULENT FEEDS

Potatoes raw	17	Not over 2 lbs. to 1 lb. grain
*Potatoes cooked	25	Not over 4 lbs. to 1 lb. grain
Mangels or turnips	12	Not over 3 lbs. to 1 lb. grain
Rutabagas	15	Not over 3 lbs. to 1 lb. grain
Sugar beets	20	Not over 4 lbs. to 1 lb. grain
Silage	....	Not suitable to pig feeding

ROUGHAGE

Alfalfa hay, chopped alfalfa, †or alfalfa meal	75	Not over 10 percent of ration
Oat hulls	---	Not suitable for pigs. Often used to adulterate prepared pig feeds
**Garbage	20	For fattening hogs (entire ration)

*Feed value is on basis of weight before cooking.

†Compared on basis of amount actually eaten, chopping or grinding saves some waste, especially in wet weather.

**Should not be fed to pigs under 75 pounds of weight and only in limited amounts to brood sows.

Finishing Pigs for Market

By

A. W. OLIVER and E. L. POTTER

This bulletin is prepared and revised with a view to putting before the stockmen of the state the results of experimental work in pig feeding that has been conducted through a series of years by the Oregon Experiment Station at Corvallis and at the Eastern Oregon Branch Experiment Station at Union. We have made no attempt to include all the data involved in these experiments but on the contrary have tried to state only the results that are immediately applicable to pig feeding in Oregon. We have made reference to the work of stations outside of Oregon wherever it has bearing on the question under discussion.

All of the data upon which this bulletin is based are on file, and full details of any of the tests can be furnished on request. No positive statements are made which have not been thoroughly proved by repeated tests.

As the title indicates, this bulletin deals with finishing pigs for market rather than with growing younger pigs or feeding brood sows. These latter subjects are reserved for later publications.

The larger number of the pigs marketed in Oregon are of light weight, ranging from 175 pounds to 225 pounds. The pigs are growing, therefore, as well as laying on fat during the finishing period, and in order to secure the very best results considerable attention must be given the question of balancing the ration so that sufficient protein and mineral matter will be given to develop muscle and bone. The finishing period need not exceed sixty days unless a rising market warrants longer feeding.

The finishing period should begin when the pig is about 100 pounds in weight regardless of age. As a rule, however, the pig that reaches 100 pounds in weight when about five months old is more economical to feed for market than one that reaches this weight at an earlier or a later age.

PREPARATION OF FEEDS AND METHODS OF FEEDING

A good many tests have been made concerning the various methods of preparing and feeding the common feed stuffs. It may be said, in general, that preparation and methods of feeding are less important than many believe, provided the feed is palatable and fed regularly. It must be remembered that no method of treatment can change the composition of the feed. Particularly is it true that no grinding, soaking, or cooking can lessen the percentage of crude fiber. Digestibility and palatability may, however, be changed to a small degree and thus affect the rate of gain and the amount of feed to the 100 pounds gain, as is indicated in the summary of results following.

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GRINDING AND SOAKING

Grains. Averages of all tests conducted at Corvallis and Union on the value of grinding small grains show a saving of 10 percent over feeding whole grains. According to a compilation of Experiment Station results by G. M. Rommel (Bulletin 47, United States Department of Agriculture), the average saving resulting from grinding small grains is 12 percent. This percentage is figured on the amounts of feed necessary to produce 100 pounds gain. The saving effected by grinding corn is less than with wheat or barley. An average of 18 trials at Wisconsin showed a saving of 6 percent in favor of ground over shelled corn, where the corn was hard and dry. Iowa reports a saving of from 4 to 6 percent. So small a saving will not usually pay for the expense of grinding, but on the other hand the advantage of grinding small grains is enough ordinarily to pay the expense of grinding.

Recent experiments at Corvallis involving sixty animals indicate rather conclusively that in respect to rate of gains, economy of gains, and daily feed consumption, there is practically no difference between the lots fed finely ground, coarse ground, or steamed rolled barley. There may be, however, a big difference in cost. Where grain is ground very fine, say to the consistency of shorts, big mills are required which cost several hundred dollars. Such mills are beyond the reach of the average stockman. The farm mills regularly on the market whether of the roller or burr type will not do very fine grinding although satisfactory for coarse grinding. The simple roller mill does very good work and does a great amount of grinding in proportion to the power used. Dry grain, especially barley, breaks up in rolling, and the product resembles that from the burr mills. Where the grain is steamed, or dampened, before rolling, the kernel does not break up but mashes out flat like oatmeal. Steaming or dampening requires additional work and equipment as compared with dry rolling or grinding and adds some moisture which may sometimes cause the grain to heat if stored in large quantities. The fact that fresh steamed rolled barley contains quite a little moisture should be given consideration in buying feed. From the standpoint of cheapness, dry rolling is therefore the best method of preparation, with coarse grinding in a burr mill next in order.

Soaking of whole grains is a partial substitute for grinding and seems advisable where grinding is unusually expensive, though further data are necessary before positive conclusions can be drawn. In soaking, care must be taken to prevent feeding too much water as gains will be retarded if the animals are forced to consume more water than they naturally require.

The soaking of grains that have been ground is of very little advantage as shown by tests at Corvallis and Union. There was no material difference between soaked and unsoaked ground grain, either as to rate of gain, feed consumed, or feed required to produce 100 pounds gain; consequently the trouble of soaking would be largely wasted. Wetting ground feed, however, may save waste when fed out of doors in dry, windy weather.

Alfalfa Hay. Alfalfa hay may be fed long, cut into short lengths, or ground into meal. Results at Union indicate that alfalfa hay fed long in racks as a grain supplement induced larger daily consumption with larger and cheaper gains than when fed either as a meal or cut. The cost of 100 pounds gain in the lot fed long hay was 42c less than where alfalfa meal was used, and 53c less than where cut alfalfa was used. These figures take into account the rapidity and economy of gains, as well as cost of preparation. Kansas reports no greater gains where alfalfa hay was ground than where fed long. Nebraska reports results of five years' experimentation, indicating clearly that the best way to feed alfalfa for fattening pigs is to feed it long and in racks. The poor showing for chopped or ground alfalfa is in all probability due to the forced consumption of stems, which contain much crude fiber. In other words, it is only the leaves and finer portion that are of value for pigs, while the coarser portions may be a detriment. The leaves and blossoms are sometimes separated from the stems and fed to pigs while the coarser portions are fed to cattle. This is a desirable practice wherever it can be done without too great expense.

Roots. Roots should always be chopped before being fed to fattening hogs. When fed in troughs separate from the grain ration, two or three inches square is a desirable size, but results at Corvallis show very clearly that much greater root consumption can be induced where the roots are finely chopped and mixed with the grain.

COOKING

Grains. Extensive experiments have shown conclusively that the cooking of grains is not only of no value but has a decidedly detrimental effect upon the feed. Corvallis experiments give uncooked grains a preference of 9.8 percent over cooked. Numerous experiments elsewhere confirm these results. Cooking seems to lessen the digestibility of protein and mineral matter but may have some slight beneficial effect on the starches.

Potatoes. Potatoes being a very starchy feed must be cooked before feeding in order to obtain the best results. In an experiment at Union, it took 556 pounds of raw potatoes to replace 100 pounds of barley while it only required 385 pounds of cooked potatoes to accomplish the same result. Experiments elsewhere confirm these results.

The degree to which potatoes are cooked is important. Tests at Corvallis have shown definitely that potatoes are more palatable when cooked until they are about to drop to pieces and form a meal. Cooking until potatoes are desirable for table use is not sufficient to make them palatable for fattening hogs.

The moisture content must be guarded, as hogs forced to consume too much water do not make the most economical use of their feed. If steamed no water need be added. If boiled the water in which they are boiled must be poured off.

Roots. Cooking does not improve roots for hog feeding purposes. This is true also of squashes, pumpkins, melons, and practically all feeds except potatoes and possibly beans.

Alfalfa Hay. Results secured at Union on the increased value of steamed alfalfa hay are not extensive enough to warrant definite conclusions. A slight advantage for steamed alfalfa is indicated, but not sufficient to justify the expense of the steaming process. Steaming alfalfa or clover for hogs at Corvallis has not proved profitable.

METHODS OF FEEDING

Hand Feeding. This method consists in giving the pigs at each feeding time the amount of feed they will require to meet their needs until the next feeding time. Under this system feed is given two or three times daily.

Self Feeding. This system consists in having a quantity of feed before the pigs at all times and in such form that it will not be trampled under foot and wasted. Results of seven tests conducted at Corvallis and Union show a saving of 38 pounds of grain to the 100 pounds gain in favor of self feeding over hand feeding. The average daily food consumption was greater and consequently the daily gain more rapid. Similar results have been obtained at other stations. The use of a self feeder reduces the feeding labor to some extent though attention must be given to the feeder once or twice a day to prevent clogging. Some care must be exercised in getting the animals on full feed.

Free Choice. Under this plan several self feeders are employed, each containing a different feed, thus allowing the pigs to balance their own ration. Iowa reports excellent results following this system. The plan involves less work than mixing the feed and putting it all in one feeder, but can not be used where it is desired to introduce some less palatable food to lessen the cost of the ration.

Hogging Down. Under this plan such crops as peas, horse beans, wheat, corn, and root crops are grown to maturity, and the pigs are then allowed to do the harvesting. Waste of feed from tramping into the ground is offset by the saving in the expense of harvesting. This is often the best method, especially where cost of harvesting is high as is the case with peas or corn or with very light crops of wheat or barley.

FEEDING STUFFS

This section of the bulletin discusses the different feeds that are generally used in the Northwest for pig-fattening purposes. The results of experiments conducted in Oregon are given to substantiate statements made, and results from other states are cited when of sufficient pertinence.

CONCENTRATES

Barley. Barley is the basis of all pig-feeding operations in the Northwest and thus has the same position in this section that corn holds in the Middle West. The barley fed is of three kinds: common feed barley, bald barley, and hull-less barley. The common feed barley is much more generally used than either of the other varieties.

A great number of experiments have been conducted at Corvallis and Union as to the value of common feed barley, and the results can be taken as conclusive. In the case of bald barley and hull-less barley fewer experiments have been conducted and definite conclusions can not be drawn. An average of twelve tests shows that it requires 438 pounds of common feed barley, ground and without supplement, to produce 100 pounds of gain. This is for barley weighing 41 to 46 pounds to the bushel. It required 404 pounds of bald barley or 475 pounds hull-less barley, both ground, to produce 100 pounds gain.

Wheat. This grain is used extensively in Oregon for fattening pigs and is commonly thought to be superior to barley, but in numerous experiments wheat has not given results quite equal to barley. The difference is very slight, however, and generally they may be considered of equal value. An average of fourteen tests shows that to produce 100 pounds gain requires 463 pounds of wheat if fed alone.

Corn. For fattening purposes corn is approximately equal pound for pound to barley or wheat. The following table indicates the results obtained at Ohio and Missouri stations:

Station	Feed	Daily gain	Feed to produce 100 pounds gain
		lbs.	lbs.
Ohio	Ground corn 9, tankage 1	1.59	366
	Ground wheat 9, tankage 1	1.59	383
Missouri	Ground corn 10, tankage 1	1.51	480
	Ground wheat 10, tankage 1	1.60	469

The results at these stations show a slight advantage for corn in Ohio and wheat in Missouri. In general feeding operations the relative prices of corn, wheat, and barley should determine the grain the producer should feed since their value, ton for ton, is practically equal.

Wheat By-products. Middlings and shorts can be used as a partial substitute for barley whenever prices justify. Experiments at Corvallis indicate that a combination of one-third middlings or shorts and two-thirds barley will give just as good returns as barley alone, but middlings or shorts fed alone as a fattening ration have not been satisfactory, gains being very slow and amount of feed necessary to produce 100 pounds gain being excessive. These feeds are not palatable when fed in large quantities and contain too much crude fiber. Bran is too bulky for a satisfactory fattening feed and can seldom be used economically.

Oats. Owing to the bulkiness (high percentage of fiber) of this feed it should not constitute the sole grain for fattening purposes. Experiments at Corvallis in which one-third of the ration consisted of oats and two-thirds of barley gave results approximating very closely those given by barley alone. Results at the Wisconsin Station in which one-third of a corn ration was replaced by ground oats indicate approximately the same relative values.

Ohio reports indicate a slightly smaller feeding value for oats than for corn. The difference is not great, however, and the feeder is fairly safe in making one-third of the ration oats providing the price of oats justifies the substitution. When fed in larger amounts than one-third of the ration, however, oats have not proved satisfactory.

Rye. Rye as a sole feed for fattening purposes is not palatable and does not give as good returns as other grains. Not only does it require more feed to produce 100 pounds gain, but gains are made less rapidly, as it seems impossible to induce the animals to eat sufficient quantities to make production satisfactory. Rye-fed pigs were lacking very much in finish as compared with the other lots.

The following table gives results of rye feeding:

Station	Feed	Daily gain	Feed to produce 100 pounds gain
		lbs.	lbs.
Oregon	Rye, ground	1.09	440
	Wheat, ground	1.6	423
Nebraska	Rye, soaked	.88	546
	Wheat, soaked	1.05	504
Ohio	Rye 9, tankage 1	1.00	441
	Corn 9, tankage 1	1.09	399

If a small proportion of rye is mixed with a larger proportion of other feed the pigs will eat it satisfactorily and make good gains.

Peas. Because of the prevailing high prices for peas they are not generally used for hog-feeding purposes. They contain about two times as much crude protein as the cereals and are high in phosphorus and potash. Peas are more efficient when fed in combination with some carbonaceous feed, such as wheat, barley, corn, etc.

The most general method of feeding peas is the hogging-down system. The peas are allowed to get ripe, and the pigs are then turned into the field to do the harvesting. This system at Union gave an average daily gain of 1.52 pounds with an average production of 397 pounds of pork to the acre. The Idaho Station reports slightly greater returns. The amount of pork produced to the acre is very largely determined by the yield of the peas. The returns are generally satisfactory considering the fact that the peas are essentially a rotation crop and that the pigs under this system do their own harvesting.

The following table indicates the value of threshed peas compared with other grain:

Station	Feed	Daily gain	Feed to produce 100 pounds gain
		lbs.	lbs.
Oregon (Union)	Peas	1.76	353
Oregon	Wheat	1.60	423
Oregon	Barley	1.54	438

From the foregoing tables it is clear that peas rank first of the grains in efficiency of pork production. The economy, however, will depend upon the relative prices and supply of these feeds.

SUPPLEMENTAL FEEDS

Supplemental feeds are feeds used as supplements to the grains such as wheat, barley, or corn, so as to make a better balanced or more palatable ration. Most cereals and cereal products are deficient in protein and the protein contained is incomplete, that is, lacking in certain compounds essential to the most rapid gains. Animal proteins, on the other hand, and to a lesser extent leguminous proteins, contain these desired compounds. But relatively small amounts of supplement are neccessary to give satisfactory results. Very large amounts of supplement may greatly increase the cost and lower the rapidity of gains, since their high value lies more largely in their influence upon the utilization of the other feeds used than upon their own independent nutritive value.

Skim Milk. This is not only the very best supplement for growing pigs, but is almost of equal value for fattening purposes. Though very low in dry-matter content, milk furnishes a complete protein, which fact accounts in a large measure for the excellent returns. Milk renders the ration more palatable, inducing greater consumption and consequently greater daily gains.

The following tables give comparative results of feeding milk as supplement to grain:

BARLEY AND SKIM MILK

Station	Ration	No. of tests	Average daily gain	Feed to produce 100 pounds gain
			lbs.	lbs.
Oregon	Barley	12	1.54	Barley 438
Oregon	Barley and milk	4	1.57	Barley 322 Milk 319

WHEAT AND SKIM MILK

Station	Ration	No. of tests	Average daily gain	Feed to produce 100 pounds gain
Oregon	Wheat	14	1.12	Wheat 463
Oregon	Wheat and milk	4	2.06	Wheat 292 Milk 330

Tests elsewhere indicate that where three or four pounds of milk are fed to each pound of grain it will require 400 pounds of milk to replace 100 pounds of grain and where milk is fed alone, gains will be quite slow, and it will require 1000 to 1500 pounds of milk to replace 100 pounds of grain.

Buttermilk. This supplement when free from wash water, is equal in feeding value pound for pound to skim milk. As in the case of skim milk it should be fed at not over 3 pounds of buttermilk to 1 pound grain in order to attain the greatest efficiency. Before paying prices equal to quotations on skim milk the purchaser of buttermilk should be sure that the product is not diluted. It is a very easy matter to dilute buttermilk with water. This dilution is also very difficult to detect unless a moisture determination is made. In order to avoid the spreading of tuberculosis buttermilk should be heated to 180° temperature if the cream has not been pasteurized before churning.

Whey. While whey is a dairy by-product and usually thought of in connection with skim milk or buttermilk, it is very low in its protein content and can not be used as a supplemental feed. It is therefore discussed further on under the head of miscellaneous feeds.

Tankage. Tankage, often called meat meal, is a by-product of the meatpacking industry. Waste meat, scraps, blood, and fat trimmings are subjected to a very high steam pressure and thoroughly cooked. The fat is then drawn off, and the residue dried, finely ground, and placed on the market under the name of Digester Tankage. There are different grades of the product, containing from 40 percent to about 60 percent protein. It is always advisable to use the grade containing the highest percentage of protein, as the value of tankage is mainly in its protein content. In general there is no advantage in using tankage in combination with skim milk or other protein supplements. Tankage added to alfalfa pasture does not seem to justify its extensive use for this purpose although the evidence on this point is not absolutely conclusive.

The following tables give value of tankage as a protein supplement.

BARLEY AND TANKAGE

Station	Ration	No. of tests	Average daily gain	Feed to produce 100 pounds gain
			lbs.	lbs.
Oregon	Barley	12	1.54	Barley 438
Oregon	Barley and tankage	5	1.61	Barley 340 Tankage 36

WHEAT AND TANKAGE

Station	Ration	No. of tests	Average daily gain	Feed to produce 100 pounds gain
Oregon	Wheat	14	1.21	Wheat 463
Oregon	Wheat and tankage	2	1.42	Wheat 330 Tankage 41
Ohio	Wheat and tankage	1	1.59	Wheat 345 Tankage 38

These tables show that 100 pounds of 60 percent tankage replaced nearly 300 pounds of grain.

Besides the foregoing results eight tests conducted at Union show that 100 pounds of 60 percent protein tankage replaced 327 pounds of grain.

These results indicate clearly the value of tankage as a protein supplement to the grains. One pound of tankage fed in amounts of from 5 to 7 percent of the ration will in general replace 3 pounds of grain. Results of two tests at Corvallis show that a ration containing 7 percent tankage gives just as good results as a ration with 17 percent; that is, the gains were as good and the total amount of feed to the 100 pounds gain no higher, thus showing that 5 to 7 percent was enough to balance the ration.

Fishmeal. Fishmeal is a protein supplement prepared from fish scraps and fish unsuited for human food. The fish and scraps are cooked, then pressed to extract the oil, after which the residue is dried and ground.

Fishmeal generally contains from 2 to 10 percent less protein than does tankage, but it contains more mineral matter, especially more calcium and phosphorus, bone-building compounds, which are important in hog feeding.

The following table gives the results of tests of tankage versus fishmeal.

Station	No. of tests	Ration		Daily gain	Average amount of feed to produce 100 lbs.	
				lbs.		lbs.
Oregon	2	Barley Fishmeal	93% 7%	1.32	Barley Fishmeal	402 30
Oregon	2	Barley Tankage	93% 7%	1.08	Barley Tankage	441 33
United States	1	Corn Fishmeal	90% 10%	2.16	Corn Fishmeal	354 39
United States	1	Corn Tankage	90% 10%	2.00	Corn Tankage	416 46

From the table it will be observed that fishmeal is more efficient than tankage as a protein supplement. The average saving in feeding fishmeal in preference to tankage is 9 percent. The relative price of tankage and fishmeal will determine which feed should be fed. Fishmeal containing less than 45 percent protein can not be expected to be as efficient as the high grade tankage.

Cocoanut Meal. Cocoanut meal is the product resulting after the oil has been extracted from the copra, or meat of the cocoanut. There are two kinds of cocoanut meal, the domestic and the Oriental. The domestic meal is made in America from copra imported from the Orient. The Oriental meal is made in the Orient, and due to the crude method of manufacturing it still contains 30 to 40 percent fat. Most of the cocoanut meal on the American market is of domestic manufacture. The use of cocoanut products is being encouraged by commercial shipping interests of the Northwest to furnish return cargo for ships that have gone to the Orient with flour and lumber.

Cocoanut meal tends to become rancid if stored for a long period, especially when it contains much moisture. Cocoanut meal varies as to palatability, as occasionally there will be a quantity that the pigs will not eat readily, probably because the fat has become rancid, although we can not be quite sure on this point.

In one test at Corvallis, growing pigs refused to eat cocoanut meal when fed as 21 percent of the ration, but in other tests they have readily eaten up to 50 percent cocoanut meal. In two tests cocoanut meal containing 43 percent fat was fed in the proportions of 25 percent and 50 percent of the total ration. In both cases the 25 percent ration proved the more satisfactory. The 50 percent had a laxative effect causing the pigs to scour. The standard domestic cocoanut meal was fed in two other tests, and each time a ration containing 25 percent cocoanut meal and 75 percent barley or wheat was the most satisfactory. In a ration of 25 percent cocoanut meal, the remainder being barley, wheat or corn, cocoanut meal is equal to any of the common grains.

Linseed Oil Meal. Linseed oil meal is the product remaining after the linseed oil has been extracted from the flax seed. It is very palatable, uniform in quality, keeps well, and is in all cases a very safe feed. It gives results similar to tankage but must be fed in double the amount as approximately two pounds of linseed oil meal is required to furnish the same protein as one pound of tankage. Tankage is for this reason usually the more economical at the usual market prices. The term "oil meal" is generally used to mean linseed oil meal, but is sometimes applied to other products resulting from the extraction of various vegetable oils.

Soy Bean Meal. Soy bean meal is the product remaining after the oil is extracted from the soy bean. It is similar to linseed oil meal in feeding value but has about 20 percent more protein and consequently a higher value. In the South the term "soy bean meal" is used to indicate the entire soy bean ground fine, without the oil having been extracted. This product, however, is not on the market in the Northwest. The soy bean meal on the market here is imported from the Orient and has had the oil extracted.

Cottonseed Meal. Because of certain poisonous properties cottonseed meal should not be used as a pig feed although it is very desirable for cattle and sheep.

Alfalfa Hay. Alfalfa hay is in some respects a desirable supplement. It contains the compounds which are lacking in the cereals, and where grown in abundance has the advantage of being relatively cheap. It is, however, so bulky that the pigs do not readily consume enough of it to balance the ration without cutting down the total amount of feed consumed. Pigs will not consume a normal amount of any ration containing more than 10 percent alfalfa hay, and this amount of hay does not contain enough protein properly to supplement the grain ration, though it is a little better than grain alone. When added to a ration already balanced, alfalfa hay is of little or no value. For these reasons alfalfa hay is not recommended for fattening pigs although it may be used for growing shoats or brood sows. (See Alfalfa Pasture.)

SUCCULENTS

These foods have a very beneficial effect upon the digestive system and produce unusually good returns in proportion to nutrients contained, but on account of their large water content they can supply only a small part of the total nutrients required. Their use, therefore, does not lessen to any large extent the amount of grain needed. When cheap, feeders are often tempted to feed succulents to excess with the result that the pigs make poor gains and do not get fat.

Potatoes. Cooked potatoes are possibly the best succulent for fattening purposes, but because of their high water content pigs will not consume a full ration if the proportion of potatoes is greater than four pounds of potatoes to one of grain. If a larger proportion of potatoes is used the pigs will gain more slowly and will put on but little finish. On potatoes alone pigs will make a very small gain in weight but will not fatten.

In several tests at Corvallis and Union with a ration consisting of four parts by weight of cooked potatoes to one part of grain, an average of 238 pounds of barley and 845 pounds of potates were necessary to produce 100 pounds gain. On this basis it required 422 pounds of cooked potatoes to replace 100 pounds of barley. Wisconsin reports that 442 pounds of cooked potatoes replaced 100 pounds of corn-meal. Denmark reports that 400 pounds cooked potates saved 100 pounds of mixed grain. These results indicate that 400 to 425 pounds of cooked potatoes will replace 100 pounds of grain (barley, wheat, corn, or mixed grains), if fed in proportions not to exceed four parts cooked potatoes to one part grain.

Roots. Roots, including sugar-beets, mangels, carrots, rutabagas, etc., are valuable when fed in limited amounts. It is not advisable to feed a ration consisting of more than three-fourths roots to one-fourth grain. On the basis of palatability the roots rank as follows: sugar-beets, mangels, carrots, rutabagas.

By actual test animals weighing 150 pounds receiving ground barley in a self feeder could be induced to eat in addition to the barley not to exceed three pounds of mangels each in a day. In a recent experiment conducted at Corvallis, however, finely chopped mangels mixed with grain in proportion of one pound of grain to four pounds of mangels were fed successfully in self feeders. The lot consisted of fifteen head, having an average initial weight of 183 pounds. The average daily gain was 1.64, and the daily feed consumption 4.66 pounds of barley and 20.8 pounds of mangels. It required 1,261 pounds of mangels and 283 pounds of barley to produce 100 pounds gain. The heavy consumption of mangels is due to mixing the grain and finely chopped mangels before feeding.

We are safe in concluding that 600 pounds of mangels will replace 100 pounds of barley if fed in proper proportions. Carrots and turnips are slightly more valuable than mangels, though not as palatable. Results from other stations show that 400 pounds of sugar beets are necessary to replace 100 pounds of grain. The difference in efficiency of the various root crops, except sugar beets, is so slight that the determining factor should be the comparative yield and cost of producing the crops. Such differences as there are seem to depend upon the dry-matter content.

Artichokes. As reported in Station Bulletin 54 one-eighth acre of artichokes supplemented with 736 pounds of mixed grain produced 244 pounds of pork. Allowing 450 pounds of mixed grain for 100 pounds gain, an acre of artichokes was worth 2,896 pounds of grain. Missouri Bulletin 29 reports artichokes practically equal to potatoes for pig feeding. Henry states the following regarding artichokes: "Although long grown in a small way and often extolled, no extended feeding trials have yet been made with artichokes, nor does their use by feeders seem to increase." Artichokes are grown to some extent on the richer bottom soils of the coast counties of Oregon but are almost unknown in the other parts of the state.

Silage. Corn silage is practically of no value in a fattening ration. Tests at Corvallis show a smaller daily gain and a greater amount of grain requirement to the pound of gain when silage constituted part of the ration than when the same ration was fed without silage. Results at the other stations confirm these conclusions. This is probably due to the large amount of fiber contained in the silage.

Silage made from the ear corn without the stalks is a very satisfactory pig feed, but the pigs leave the cobs and husks and eat only the kernels. There seems to be no advantage in putting ear corn in the silo instead of putting it in the crib.

MISCELLANEOUS FEEDS

Molasses. Cane molasses can be used to advantage in combination with other feeds. Tests at Corvallis show that one lot of fifteen pigs receiving four parts mill-run and one part molasses consumed as much mill-run as similar lots receiving mill-run alone. The gains were proportionally better, thus making cane molasses more efficient than mill-run and at the same time inducing greater consumption and greater gains.

In another test recently conducted at Corvallis fifteen pigs having an average initial weight of 183 pounds, consumed daily 10.7 pounds of a mixture of ground barley 72 percent, tankage 8 percent, and molasses 20 percent. They made a daily gain for 50 days of 2.11 pounds. In this test molasses proved practically equal pound for pound to ground barley.

In a test at Corvallis, one lot of pigs were fed as high a proportion of molasses as was possible, to determine how much they could consume without any detrimental effects. The pigs were started on a 30-percent ration and gradually increased until they were receiving 43 percent of the ration molasses. Molasses has a laxative effect and causes the pigs to scour.

Molasses is especially good to mix with other feeds of an unpalatable nature. It is a valuable feed when it does not cost more than barley, wheat, or corn. Molasses is used chiefly, however, by feed manufacturers in the preparation of mixed feeds. These dealers get molasses in tank cars and at a much cheaper rate than farmers who have to buy it in barrels and in small lots. Barreling adds approximately 50 percent to the cost of molasses. Farmers usually dislike molasses because it is unpleasant to handle.

Whey. Whey contains a small amount of carbohydrate material and is valuable to this extent, but should be fed in combination with grain and a protein supplement. Fed as indicated, whey has a feeding value equal to about one-sixteenth or one-twelfth that of grain. These results are determined from the use of ordinary whole whey, which according to Day is worth 25 percent more than separated whey. Hogs can not be fed entirely on whey because it contains too much water.

Garbage. Garbage can be utilized as a hog feed without any detrimental effects on the pork produced although popular opinion is to the contrary. The only effect garbage has on the hogs is that it makes them rather "paunchy" and in that way lowers their dressing percentage.

In several tests at Corvallis, with garbage from the dormitories, it required from 1500 pounds to 2000 pounds to produce 100 pounds of gain. As high as 1.5 pounds gain per day has been made by pigs fed on garbage alone. Restaurant and hotel garbage has a higher feed value than family garbage. It is not necessary to cook garbage, in fact it is an additional expense and does not increase the feed value unless the garbage is nearly all potato peelings. Cooking does not control the spread of disease and it is always necessary to vaccinate the hogs in case cholera is prevalent. Some feeders cook garbage in order to remove the grease, which they sell as soap grease, but the grease ordinarily does not pay the expense of cooking. In order to skim the grease off it is necessary to add enough water to cover the garbage, which increases the bulk and reduces the feed value. In addition the grease has a feed value to the pigs of about two times the value of grain.

Since the supply of garbage always varies from day to day it is a good plan to have pigs enough to eat up all the garbage at all times and then when there is not enough garbage, make up the deficiency with grain. Garbage should always be fed fresh as there is no very satisfactory way of storing it.

Hogs that are fed garbage from a city should be vaccinated for hog cholera.

When grain is fed to reduce the pig's "paunchiness" we should feed only grains that have a small amount of crude fiber such as barley, wheat, or corn. Such feeds as mill-run or oats are too bulky and cause the same "paunchy" condition as garbage.

In tests at Corvallis, it was proved that garbage does not need a protein supplement such as tankage or fishmeal, as there seems to be sufficient protein in the garbage to balance the ration.

Beans. Cooked cull beans, according to the Michigan Station, fed with equal parts of corn made 1.5 pounds gain per day and require 406 pounds of feed to produce 100 pounds gain. When a straight ration of cooked beans was fed, the daily gains were not as much and it required more feed per 100 pounds gain. A ration composed more than one-half of cooked beans causes soft pork.

PASTURE CROPS

Alfalfa Pasture. There is considerable question in the minds of farmers as to the advisability of allowing fattening pigs pasturage in combination with their grain ration. Results at Union show that it is advisable providing the animals are marketed under 200 pounds. Under these conditions alfalfa pasture made a saving of 88.61 pounds barley to the 100 pounds gain.

Following is a table of results obtained at Wichita Union Stock Yards:

Feed	Daily gain	Feed to produce 100 lbs. gain
	lbs.	lbs.
Corn	.77	Corn 560
Corn and alfalfa pasture	1.63	Corn 393
Corn and meat meal	1.47	Corn 409, Meat meal 19
Corn, meat meal, and alfalfa pasture	1.48	Corn 390, Meat meal 17

This table shows a great advantage for alfalfa pasture and corn as compared to corn alone. The average initial weight of the hogs used was approximately 120 pounds; thus they were growing during the fattening period. These results indicate the inadvisability of using corn alone as a ration for growing pigs. In the corn and meat-meal ration alfalfa pasture effected a saving of 19 pounds of corn and 2 pounds of meat-meal to the 100 pounds gain.

In general, light-weight hogs can utilize pasture to the best advantage. Pasture for fattening pigs must be good in all cases and the grain not limited.

Clover Pasture. Clover pasture and rape pasture are of about equal value for hogs. They will not yield as much as alfalfa but will grow in localities where alfalfa will not grow and are especially suited to the Willamette Valley. Clover will furnish pasture earlier in the season than will rape, while rape is at its best during the summer when clover is getting woody. Clipping clover when it is getting stemmy or woody will induce a new growth and greatly improve the pasture. Red clover is the most satisfactory variety for hog pastures. It is seeded at the rate of 8 to 10 pounds per acre.

Rape Pasture. Rape can be sown either in rows or broadcasted. Sowing in double rows so it can be cultivated is generally more satisfactory for pasture in dry weather. It may be sown with a grain drill leaving the first two holes open and plugging the next three holes, then leave two holes open, and so on across the drill. Rape should not be sown until the weather and the ground are warm, and it should be cultivated after each rain to keep down weeds and conserve moisture.

Rape should not be pastured until it is about ten or twelve inches high. After rape has been grazed down to four or five leaves to the plant, the hogs should be changed to another pasture and the rape cultivated. Then after a short time it can be pastured again.

Seed rape at about 5 pounds per acre in rows and about 8 pounds when broadcasted. It is probably our best pasture in Western Oregon.

Winter Wheat. Winter wheat planted in the spring makes a good hog pasture for Western Oregon. It yields only about two-thirds as much as rape or clover but it is better suited to poor undrained soil. It is necessary to keep the wheat grazed to about three or four inches high or the wheat will head and stop growing. Winter wheat may often be grazed the second season. Seed about two bushels per acre.

Vetch and Oats. Vetch and oats are not as satisfactory as the foregoing crops. They do not stand the grazing as well and do not grow well after being once eaten off.

IMPORTANT CONSIDERATIONS IN BALANCING RATIONS

Crude Fiber. An important factor, and one that frequently receives little consideration in balancing rations for fattening pigs is crude fiber. This comprises the woody portion of the feeding stuffs and consists mainly of cellulose, which is much less digestible than other constituents of the feed. It is a high content of crude fiber that makes a ration "bulky."

The cow, the sheep, and the horse have special digestive arrangements, whereby crude fiber may be digested in large quantities. Fiber is in fact necessary for the well-being of these animals. The hog, however, is not so constituted. He is especially fitted for consumption of large quantities of concentrates which he converts into edible product much more efficiently than any other meat-producing animal, but he can digest crude fiber to but a limited extent, if at all. Large quantities of fiber have a detrimental effect and some authorities consider any crude fiber detrimental.

If the fiber content of the ration exceeds 5.5 percent, it is impossible to make good gains in fattening hogs. Small quantities of crude fiber in a fattening ration do little harm, but the limit is easily reached and is too often passed. Canadian laws on feed regulations stipulate that feeds being placed on the market for pig feeding purposes must not contain to exceed 6 percent crude fiber.

A few examples will make this conclusion evident. Experiments have shown that alfalfa hay, though containing a high quality of protein and other digestible nutriments, will barely maintain hogs if fed as a sole feed in a ration. The feed contains 28 percent crude fiber. To make satisfactory gains a 200-pound fattening hog would have to consume daily 15 to 20 pounds of alfalfa hay. The consumption of this amount is a physical impossibility.

Such feeds as wheat bran, containing fiber 10.2 percent; wheat shorts, containing fiber 7 percent; barley shorts, containing fiber 10.1 percent; oats bran, containing fiber 18.3 percent; barley bran, containing fiber 19.3 percent; oat hulls, containing fiber 29.2 percent; oats, containing fiber 10.9 percent, are all too high in crude fiber content when fed as a sole feed in a fattening ration. Numerous experiments have clearly shown that they do not give satisfactory gains unless fed with other feeds, low enough in fiber so that the fiber content of the mixture is less than 5.5 percent.

Experiments at Corvallis have shown that a ration consisting of two-thirds barley, one-third shorts, is equal to barley. This combination gives a crude fiber content of 5.4 percent, just under our limit. Experiments at Corvallis and other places have shown, likewise, that a ration consisting of one-half shorts and the other half barley is not equal to barley alone. This combination gives a fiber content of 5.9 percent, which is above our standard. Similar experiments have shown that two-thirds corn and one-third oats equals corn alone. The fiber content in such a ration equals 5 percent. A ration two-thirds barley and one-third oats is barely equal to barley. The fiber content is approximately 6 percent. Many more experiments are available and could be cited to support the principle that the crude fiber content of the ration should not exceed 5.5 percent.

A great number of commercial hog feeds are advertised with emphasis on their protein and carbohydrate content. These nutrients, though very important, are of little value in the presence of too much fiber. Alfalfa hay, for example, contains a high percentage of protein and a fair amount of carbohydrates, but, as stated above, it would be impossible to fatten hogs on alfalfa hay alone. If the purchaser of feeds will pay more attention to fiber content he will obtain much greater returns.

In selecting feeds the purchaser may be guided by the following principles: Feeds containing 2 percent to 5.5 percent fiber are concentrates ordinarily suitable to pig fattening. Feeds containing 10 percent to 15 percent fiber are bulky concentrates satisfactory for horses and cattle but not for hogs unless mixed with large quantities of more concentrated feeds. Feeds containing 20 percent to 30 percent fiber are roughage and must be fed as such, no matter how finely they may be ground. Feeds containing over 30 percent fiber must be classed with the straws and are not ordinarily worth buying.

Protein. The protein question is always important in pig feeding as nearly all the common grains are deficient in protein. Some of the cereal by-products contain enough protein but it is not of the proper quality. It becomes necessary, therefore, to supply this lack with some feed that contains a high percentage of protein and in which the protein is the proper kind. Such feeds are tankage, the oil meals, skim milk, buttermilk, and within certain limits alfalfa. The pig seems to require animal or legume protein, but when once the protein requirements of the animal are met it is of no advantage to add more; in fact, it may be a disadvantage. The high values often obtained from tankage or skim milk are not to be obtained when these feeds are given in larger quantities than enough to furnish the necessary protein. The optimum amount of digestible animal or legume protein for a fattening pig is about one-fourth pound a day.

Minerals. Our definite information on the value of minerals for hogs is limited. It is known, however, that the hog should be given some minerals to supplement the grain rations since the grains in these climates are deficient, especially in calcium, or lime.

Hogs that are not receiving enough minerals will generally become lame and sometimes paralyzed in the hind quarters. Purdue University in a recent experiment found that a mineral mixture of wood ashes, acid phosphate, and salt increased the daily gains and made the gains more economical with a ration of soy beans and corn.

The following mineral mixture can be fed either by adding about one-tenth pound per day per hog to the ration or by keeping it before them at all times in a self feeder.

Slacked coal	100 pounds
Stock salt	8 pounds
Ground bone (fine)	4 pounds
Ground sulfur	1 pound
Air-slacked lime	2 pounds
Glauber's salt	2 pounds
Potassium iodine	0.4 pound

Thoroughly mix all the ingredients except coal together before mixing with the slacked coal.

Water. The pig needs good, clean water accessible at all times. Water in the feed and water in the trough are the same to the pig providing there is not too much in the feed so that he has to consume too much water in order to get enough feed. While our information on this subject is not as definite as we should like, it seems that the entire ration for a fattening pig should not contain more than 60 percent water and that if it does contain more than 60 percent the pigs will not consume enough feed and will make slower gains and take on less finish.

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A Chemical Study of Legumes and Other Forage Crops of Western Oregon

By

J. S. JONES and D. E. BULLIS

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A Chemical Study of Legumes and Other Forage Crops of Western Oregon

By J. S. JONES and D. E. BULLIS

The growing of legumes is fundamental to a thoroughly well-developed agriculture in Western Oregon. However widely this fact is known and acted upon it cannot be over-emphasized by repetition. It is common farm experience that no procedure is more generally applicable for the rejuvenation of soils too long given over to the continuous growth of small grains and for stimulating the latent fertility of newly cleared lands than the systematic and persistent growth of the clovers, vetches, and other adaptable legumes. When, in addition to the value directly of legumes as rejuvenators of poorly conditioned soils, mention is made of their enormous feeding value and their indirect value as soil builders in the shape of barnyard manures, no argument is necessary in support of the fundamental relationship the legume crops bear to agriculture in Western Oregon. There are no crops here of greater importance, for they make the growing of other crops permanently possible and profitable.

Closely associated with legume crops are other forage crops, which, although not in any sense fundamental to the general agriculture of Western Oregon, are of vast importance economically, because of their extensive use in the feeding of dairy and other livestock. It is the sole purpose of this publication, one of a series dealing with some chemical phase of forage crop production and utilization, to carry over to farmers of Western Oregon some specific information regarding the chemical nature of these crops which so vitally affect their own immediate interests and the permanent general welfare of Western Oregon. In this instance information gained from rather extensive laboratory investigations harmonizes with and supplements that secured by farm experience. It is usable in that it makes for a better understanding of the requirements of forage crops for growth, their peculiar and relative values for the feeding of livestock, and the invigorating effect of the legumes on poorly conditioned and "run down" soils.

THE COMMONLY GROWN LEGUMES

ADAPTABILITY

Conditions of soil and climate which make of alfalfa the forage crop of first importance in irrigated sections of Eastern Oregon somewhat restrict its growth in Western Oregon, particularly in Willamette Valley and Coast counties. There is, however, a rather extensive acreage of river bottom lands in the Valley counties on which alfalfa is known to thrive excellently and on which its growth might be greatly expanded with benefit to the soil and the production of a greater tonnage of hay of a kind that is always in demand by feeders of dairy stock.

The clovers—red and alsike—adapt themselves to a wide range of conditions with respect to soil type and climate. They are extensively grown in Valley and Coast counties where the reaction of the soil is not too strongly acid. Red clover is given the preference on the higher lying and well drained lands. Alsike, because of its adaptability to soil conditions incident to poor natural drainage, is confined almost exclusively to areas of that kind. The clovers are prominent among the legumes of Western Oregon.

The ability of common vetch to thrive on close-textured and somewhat acid soils gains for it, too, a peculiar significance for the agriculture of Western Oregon. It is thrifty and hardy under a wide range of soil conditions. Its ability to secure nitrogen under conditions that are adverse to other legumes and to store it as finished protein (muscle-building material) for the use of dairy and other livestock is an exceedingly valuable characteristic and one that might possibly by selection and breeding be made even more pronounced.

Other legumes, hairy vetch, field peas, and beans, are less widely grown, but each possesses some peculiar characteristic that makes it valuable for certain localities. No section of Western Oregon is without some legume that makes excellent growth and lends itself to soil-improvement programs and the feeding of livestock.

THE LEGUMES AS SOIL REJUVENATORS

It is common observance that newly cleared lands all too frequently are lacking in something that imparts "tone" and vigor to cultivated crops. Farm experience, too, teaches that soils, no matter how excellent the original condition of tilth, when continuously cropped with small grains or with small grains rotated only with non-leguminous forage crops, or even when "clean cultivated" for too long a time, as in orchard practice, invariably come into a condition of poor tilth and a lessened capacity for production. It is the peculiar function of legumes to overcome these conditions.

Soils fail to impart "tone" and vigor to growing crops largely because of an insufficient supply of nitrogen, one of the elements absolutely essential for the growth of all plants. Soils reach a "run-down" physical condition through failure to maintain in them a liberal supply of actively decaying organic matter. Nitrogen can be purchased in the form of commercial fertilizers, and sometimes such purchase is practicable. Barnyard manures will carry into the soil active forms of organic matter. But all too frequently commercial forms of nitrogen are too expensive for general use and barnyard manure is sufficient for a small fraction only of the soil that would be stimulated to greater production by its application. Just here the legumes can be made to save the situation.

The deep-rooted ones, like alfalfa and the clovers, enrich the soil enormously with sod-like masses of quickly decaying roots when the ground is broken for the succeeding crop. Such crops having brought up, too, from soil depths not ordinarily reached by fibrous-rooted plants, supplies of lime, potash, and phosphorus for their own nourishment, the succeeding crop has placed within its reach as the sod rots a supply of mineral plant food that would not otherwise become available to it. But these legumes, when vigorously inoculated with nitrogen-gathering bacteria, accomplish even more in the matter of placing necessary plant food at the disposal of the succeeding crop. Because of the activity of the bacteria which grow on them, the root masses are rich in a form of nitrogen that readily becomes available for the succeeding crop as the sod decays, and, best of all it has been taken largely from the unlimited supply of the soil air.

Unquestionably, these deep-rooted legumes are deservedly popular as rejuvenators of run-down lands wherever soil conditions permit of thorough inoculation and vigorous growth.

The annual legumes—vetches, beans, and field peas—when thoroughly inoculated with vigorously active nitrogen-gathering bacteria, likewise leave in their roots at harvest time a supply of nitrogen taken from the soil air which readily becomes available for the succeeding crop at no expense to the soil itself. The less extensive root systems of the annual legumes, however, put them at a disadvantage in comparison with alfalfa and the clovers in the matter of soil enrichment with active organic matter. The disadvantage is partly offset by the possibility of a more frequent appearance of these annual legumes in crop rotations and their less exacting requirements for growth. Whenever heroic treatment is necessary for the rejuvenation of soils in especially poor condition of tilth the annual legumes are readily available as cover crops. They have a well-established place in the agriculture of Western Oregon from the standpoint of soil fertility alone.

USING LEGUME CROPS

Alfalfa, red and alsike clover are most commonly cut for hay. The vetches and field peas are most frequently grown with wheat, oats, or barley and harvested for hay or silage. However harvested, the legumes figure prominently in the winter rations of sheep and cattle and are given first place among all forage crops because of their relatively large content of protein.

THE NON-LEGUMES

Of the non-legumes, some, as timothy, redtop, orchard grass, and rye grass are widely known and appreciated. Others, like marshland grass and canary grass, are localized crops whose utility is correspondingly restricted. Corn and sunflowers may very properly be mentioned in this connection as crops are more frequently harvested in Western Oregon for forage than grain. The non-legumes are less sensitive than legumes to soil reactions and are not likely to fail in any community because of acid-reacting soils.

The non-legumes, however, are soil exhausters. They have a place in rotations with small grains but like them they leave no accumulation of nitrogen in the soil in exchange for other plant foods taken. No one should think of growing timothy and orchard grass for reasons that make alfalfa, clover, and vetch so widely grown. In the form of hay the non-legume grasses bring into the ration a necessary roughage that is more palatable than the straws, comparatively cheap carbohydrates (energy-releasing and fat-producing compounds), and liberal amounts of mineral matter. Sunflower and corn silages impart to the winter ration of sheep and cattle the necessary succulence and are valued highly by feeders of dairy and other livestock for that reason alone.

COMPOSITION OF FORAGE CROPS

There are some analytical data available for practically all kinds of forage crops grown in Western Oregon. Clovers and alfalfa especially have been very frequently the objects of chemical investigations elsewhere and something is known of their response in composition to changes of environment. The data for two or three of the legumes which figure prominently in the agriculture of Western Oregon are, however, rather meagre, and it is doubtful whether any are as strictly applicable to prevailing conditions as one might wish. This situation is remedied by the analytical data presented here. They bear strictly upon forage crops grown in Western Oregon.

ORIGIN OF SAMPLES

Samples from which analyses were made represent crops of 1919 and 1921. They were obtained through the cooperation of county agricultural agents and from the superintendents of the branch experiment stations in Jackson and Clatsop counties. All samples represent crops matured for hay or silage. Since they were hand-picked and very carefully handled in drying to prevent shattering of leaves and small stems, they probably more nearly represent the crops as grown than would samples secured behind mower and rake. The analyses were made on air-dry samples finely ground.

ANALYTICAL DATA

Although the analytical data are tabulated by sections, it must not be assumed that rigid comparisons, whereby the superiority of one section over another for the growing of any one crop might appear to be established, are thereby intended or invited. So many factors are concerned in the final make-up of plant substance that one is not justified in attempting such comparisons here as the three divisions of tabulated data naturally suggest. The more or less natural geographic divisions of Western Oregon were used in the tabulation of analytical data entirely as a matter of convenience for reference and comment. It is to be noted that the greatest range of forage crops prevails in the Valley counties.

The analytical data are presented in detail in tables I, II, and IV. It would be presumptuous to undertake interpretation of or to comment on the data from the various possible standpoints of interested readers. It would be equally presumptuous to leave to the reader all possible interpretations. The data will be viewed most naturally from the standpoint of the feeder of livestock, but they have a certain value agronomically from the standpoint of soil fertility. Comment here has been restricted to these two points of view, and for the benefit of those who might best appreciate a condensed expression of results, certain calculations have been made from the original data and summarized in tables III, V, and VI. The reader may therefore study the data from his own particular standpoint, or he may quickly secure the essential points applicable directly in calculating rations for livestock and for calculating the fertilizer requirements of the more prominent of these crops.

FROM THE STANDPOINT OF NUTRITION

The Proteins. In Table I the analytical data are presented in a form that is perfectly familiar to those most likely to use them. The significance of each group of compounds in feeding operations is well understood, but this with reference to the proteins must be said: The proteins of seeds—corn, wheat, oats—because of fundamental differences in molecular structure, differ very markedly in their ability to meet the varied wants of the animal body. It is probable that the proteins of the stalks and leafy portions of the same plants also differ in feeding value for similar reasons. Actual feeding experiments are now considered necessary to establish fully the relative feeding values of protein mixtures from various sources. The "crude protein" determinations, however, still serve as a rough measure of relative values in so far as the nitrogen-containing compounds are concerned and are presented here with that idea only.

It appears from Table I that of the commonly grown legumes, common vetch and field peas stand out most prominently in ability to elaborate protein compounds. If, pound for pound, the proteins of these crops should prove to be the equal in feeding value to those of red clover and alfalfa, it would seem to be perfectly proper to encourage their more extended growth and to capitalize for the Valley and Coast counties especially this ability to gather and utilize nitrogen under conditions that are somewhat adverse to the most thrifty possible growth of the clovers and alfalfa.

Table III summarizes the average composition of those crops that are most commonly used in feeding cattle and sheep. In Table V, column 3, there is a statement of pounds of crop required to equal the protein in 100 pounds of milk. Since a fraction only of the protein consumed is digested (roughly 63 to 70 percent for the hays and silage and 70 to 75 percent for the grains) and since there are body wastes to make good as well as milk to secrete, it is obviously impossible for the dairy cow to secure from the richest of legume roughage an amount of protein sufficient to meet her requirements in reasonably heavy milk production. The non-legumes are wholly inadequate, hence the importance of the concentrates (by-products of various kinds rich in protein, as bran, shorts, linseed meal) for this particular kind of feeding.

Carbohydrates Other than Crude Fiber. It has been the custom in the analysis of plant substances intended for feeding purposes to determine "crude fiber" and to report all other carbohydrates under the term "nitrogen free extract." That custom was followed in the compilation of Table I. "Nitrogen free extract," however, like the term "crude protein," is one that covers over a great deal of information that might possibly be made use of by feeders of livestock were it readily available. In Table II are summarized for the legumes the analytical data resulting from the determination of the more prominent components of a group of constituents common to all feeding stuffs that are usually lumped together under a heading that leaves much to be desired in the way of specific information. It is to be noted that sugars, starch, and pentosans make up a large part of the "nitrogen free extract." Total sugar is the sum of "reducing sugars," calculated as dextrose, and sucrose or cane sugar. When the sweetness of the blossoms and their attractiveness to honey-bees and other insects are recalled, one would expect to find in this class of feed stuffs rather large amounts of these carbohydrates. The pentosans are carbohydrates that yield in processes of digestion sugars called pentoses. Galactans are closely associated with the gums and mucilage-like compounds of plant structure. In processes of digestion they probably also yield a sugar called galactose. The sugars and starch vary rather widely in amount among individual samples of any one kind of legumes; the pentosans and galactans are fairly constant in amount.

It is commonly assumed that the several carbohydrates of plants have practically the same value as fat-producing and energy-releasing substances. It is possible, however, that with this group, as was the case with the proteins, the utilization of each individual carbohydrate by the animal body in metabolic processes might repay more extended experimentation than has heretofore been given it. Different legumes, either alone or in mixtures with non-legumes, are not siloed with the same degree of success. Alfalfa is probably as difficult and field peas as easy as any legume to silo successfully. The presence of liberal amounts of fermentable sugars is believed to make for success in the siloing of forage crops. The data on the sugars in Table II tend in a general way to support that view.

Fatty Substances and Crude Fiber. Fat-like compounds of the forage crops are even smaller in amount than the data in the column headed "ether extract" indicate, for other substances than fats and oils are extracted with that solvent. In the grains the amount is appreciable and is to be reckoned with in compounding rations. On the other hand "crude fiber" or the fibrous portion of stalk and leaf, is large in all forage plants and low in the grains. In compounding rations the digestible portion is rated as carbohydrate and given the same value as an energy-releasing and fat-producing substance. There is a fairly wide range in the crude fiber content of samples representing any one kind of forage crop, but in all forage crops the crude fiber content is large.

Ash or Mineral Content. In Table I, under the heading "ash," is indicated the total mineral matter these forage crops contain. Animal life is practically dependent upon plant life for the mineral or inorganic portion of its make-up. Forage crops carry to dairy stock especially a large part of the mineral elements required for growth and milk production. They are for this class of livestock especially important from the standpoint of mineral nutrition.

Of the ash constituents of feedstuffs, phosphates, lime, magnesia, potash, and sulfur, give most concern, furnishing as they do the phosphorus, calcium, magnesium, potassium, and sulfur which enter into the make-up of bones, flesh, blood, milk and other body secretions. The percentages of these elements in forage crops, calculated on the air-dry plant substance, on the plant substance with all water removed (oven-dried), and on the crude ash are given in detail in Table IV. In view of the great diversity of soil types and climatic conditions that prevail within any one of the three sections under which the data have been tabulated the wide range in the percentages found for each of the several mineral elements in each of the forage crops is not surprising. From these data, however, one can calculate approximately the amount of the several mineral elements the forage crops offer to the animal body when they become a part of the daily ration.

MINERALS IN FORAGE CROPS ARE POSSIBLY LOW

There appears to be a fairly well established conviction among feeders of dairy stock in Western Oregon that Valley- and Coast-grown forage crops mature with smaller percentages of the mineral elements than the same crops east of the Cascades and in the prairie states. In the breeding of herds for heavy milk production it is believed by some at least, that real difficulty here and there is being experienced in providing rations sufficiently high in the several mineral elements to meet fully the animal's requirements. At any rate there is in the Valley all too frequently an actual physical breaking down of animals in heavy milk production and other disturbances—even diseases—not confined alone to dairy stock that serve to center inquiry around questions relating to the possible deficiency of mineral substances in available rations. The analytical data produced here cannot be made to answer positively any of these questions. It is only from analytical work on specific rations fed for specific purposes that one can arrive at definite conclusions as to the adequacy or inadequacy of their mineral content. The present work emphasizes the necessity for just that kind of investigation. In the meantime, in the compounding of rations for milk production it might be worth while, as in the case of the proteins, to note the calculations on the mineral elements recorded in Table V.

The dairy cow, for example, puts as much phosphorus into 100 pounds of milk as there is in 65 pounds of red clover hay, 47 pounds of alfalfa hay, 44 pounds of vetch hay, 30 pounds of oats, or 31 pounds of barley; as much calcium as there is in 11 pounds of alfalfa hay, 13 pounds of red clover hay, 17 pounds of vetch hay, 516 pounds of oats, or 716 pounds of barley. She puts as much potassium into 100 pounds of milk as she consumes with 8 pounds of red clover hay, 9 pounds of vetch hay, 8 pounds of alfalfa hay, 32 pounds of oats, or 34 pounds of barley; and as much sulfur as she gets in eating 7 pounds of alfalfa hay, 13 pounds of red clover hay, 12 pounds of vetch hay, 9 pounds of oats, or 11 pounds of barley.

Since, like protein and other organic nutrients, a part only of the mineral portion of feedstuffs is retained by the animal body in processes of digestion, and since again there are needs for the mineral elements for purposes aside from milk secretion, it seems reasonable to question whether the heavy producer of milk can really secure from these forage crops enough, especially of calcium and phosphorus, to meet her requirements. Feedstuffs are readily available at all points in Western Oregon in the form of various concentrates for use in balancing rations from the protein-carbohydrate standpoint. There will be greater difficulty in making good any deficiency in the mineral elements of standard rations that may be established.

FORAGE CROPS IN RELATION TO SOIL FERTILITY

In the opening paragraphs of this discussion of the forage crops of Western Oregon, emphasis was placed on the peculiar and outstanding value of the legume crops when used primarily for giving "tone" to newly cleared lands and for rejuvenating others that for some reason are in a run-down condition. It is explained that the value of the legume over the non-legume for soil improvement purposes was traceable to an association of bacterial activity and the legume root system from which the legume profited by securing the nitrogen it requires for growth, not from the soil but from the soil air. When working at its best this association not only relieves the soil from the necessity of furnishing nitrogen for the growth of the legume but accomplishes an addition of organic nitrogen to the soil in amount equal to that built into the legume root system. This of course is then available for the succeeding crop and the tendency for nitrogen to become the limiting factor in crop growth is to that extent overcome. It was further explained that deep-rooting legumes like the clovers and alfalfa not only produce a heavy sod but secure during growth from soil depths far beyond the feeding range of fibrous-rooted plants large amounts of potash, lime, and phosphates, which are left in the surface soil in easily available condition for the succeeding crop as the sod decays. For all other essential elements of growth the legumes are as dependent upon the soil in which they grow as the non-legumes.

FURTHER USE OF TABLE IV

The analytical data in Table IV can be used to show not only how much of the mineral elements the forage crops carry in rations made up for dairy and other livestock, but, approximately at least, the demand they make on the soil during growth for the various essential elements.

It is plain that the tax of the legumes on the soil is heaviest for calcium and potassium. The non-legumes—timothy and orchard grass—call for approximately as much potassium as do the legumes but for far less calcium. The soils of Western Oregon appear to be perfectly able to meet the heavy demands on them for potassium, but there are some whose content of lime in available condition is too small to meet the exacting requirements of legume crops for calcium. Additions of limestone in fertilizer form not only give to those soils a needed element of plant food but stimulate the associated nitrogen-gathering bacteria to greater activity by at least a partial neutralization of soil acids. The nitrogen-gathering bacteria which associate themselves with legumes of different kinds are not equally sensitive to the presence of soil acids but there is a limit in the intensity of acidity beyond which even the most resistant will not grow. Limestone then has a double function in the soils of Western Oregon in the growing of legumes. When soil conditions are such that the nitrogen-gathering bacteria cannot grow, then legume crops fail of their purpose in "toning" up new soils and rejuvenating old ones and become as truly exhaustive of soil nitrogen as are the non-legumes.

Sulfur is required by the legumes and other forage crops in smaller amounts than any other essential element listed in Table IV. For some reason, however, not perfectly understood but primarily because of the rather small amounts of sulfur in some soils, sulfur-carrying fertilizers have stimulated them to a remarkable increase in yields of clover and alfalfa. On this account largely sulfur is listed in Oregon among other commercial fertilizers.

Table VI was calculated from the original analytical data of Table IV. It brings out sharply a fact that is sometimes lost sight of. A given weight of any crop represents a perfectly definite draft upon the soil for just those elements of fertility that give it value. In good farm practice the net value of that draft is reduced appreciably by the careful conservation and return of all barnyard manure and litter resulting from feeding operations. Conversion of the data into cash values may be accomplished by simple multiplication when the price per pound of the various fertilizing materials mentioned is known.

In compiling Table VI there were assumed commercial fertilizers of a degree of purity readily obtainable from the fertilizer trade—92 percent sodium nitrate, superphosphate carrying 17 percent P_2O_5, 90 percent limestone, sulfate of potash carrying 48 percent K_2O, muriate of potash carrying 50 percent K_2O, and 95 percent land-plaster. The legumes, of course, for reasons already stated, should be charged only for the mineral elements used.

TABLE I. PERCENTAGE COMPOSITION OF LEGUMES AND OTHER FORAGE CROPS.

Crop	Where grown County	Calculations on air-dry basis						Calculations on oven-dry basis				
		Water	Ash	Crude protein N x 6¼	Ether extract	Carbohydrates		Ash	Crude protein N x 6¼	Ether extract	Carbohydrates	
						Crude fiber	Nitrogen-free extract				Crude fiber	Nitrogen-free extract
		Valley Section										
Alfalfa	Columbia	5.88	6.00	9.00	1.30	35.83	42.00	6.40	9.56	1.38	38.07	44.59
	Columbia	8.06	5.53	9.69	.79	31.23	44.70	6.02	10.58	.86	33.98	48.60
	Benton	6.96	6.67	10.58	1.17	32.38	42.24	7.15	11.37	1.26	34.78	45.44
	Benton	7.96	8.81	17.78	1.18	26.92	37.35	9.76	19.26	1.28	29.20	40.50
	Benton	7.62	6.94	13.38	1.38	28.28	42.40	7.50	14.50	1.49	30.60	45.91
	Benton	11.32	7.83	15.50	.70	29.95	34.70	8.83	17.49	.79	33.75	39.14
	Benton	7.62	6.59	11.94	1.14	31.69	41.02	7.14	12.95	1.23	34.27	44.41
	Average	7.92	6.91	12.55	1.09	30.90	40.63	7.54	13.67	1.18	33.52	44.09
Clover red	Columbia	7.87	4.82	8.50	1.37	28.98	48.46	5.22	9.25	1.49	31.47	52.57
	Columbia	8.85	5.38	8.19	.98	32.02	44.58	5.90	8.98	1.07	35.15	48.90
	Washington	6.91	6.42	11.50	1.65	28.84	44.68	6.95	12.38	1.77	31.00	47.90
	Linn	7.62	5.65	10.19	1.51	23.57	51.40	6.19	11.00	1.63	25.70	55.48
	Linn	6.77	5.12	8.94	2.11	26.50	50.56	5.60	9.56	2.60	28.40	53.84
	Linn	7.63	5.56	11.13	1.80	29.62	44.25	6.02	12.07	1.96	32.07	47.88
	Linn	7.85	5.38	9.62	1.39	27.41	48.35	5.84	10.43	1.51	29.75	52.47
	Linn	8.15	5.70	9.69	1.31	27.75	47.40	6.20	10.54	1.43	30.22	51.61
	Linn	6.98	6.62	10.42	1.35	25.10	49.53	7.20	11.20	1.45	26.96	53.19
	Linn	8.56	6.78	9.80	1.59	29.21	44.06	7.42	10.72	1.74	31.97	48.15
	Linn	8.73	6.68	10.74	1.47	31.23	41.15	7.32	11.78	1.61	34.23	45.06
	Benton	9.71	5.47	11.12	1.43	21.02	51.25	6.05	12.31	1.58	23.25	56.81
	Benton	6.22	5.92	11.92	1.79	23.20	50.95	6.46	12.75	1.91	24.13	54.75
	Benton	8.19	6.44	11.20	1.71	23.07	49.39	7.00	12.19	1.86	25.12	53.83
	Benton	8.52	5.40	10.12	2.08	23.36	50.52	5.87	11.06	2.27	25.54	55.26
	Benton	7.48	6.71	10.39	1.22	23.02	51.18	7.18	11.18	1.32	24.87	55.45
	Benton	11.11	6.92	11.37	1.19	26.56	42.85	7.80	12.81	1.34	29.89	48.16
	Benton	7.36	6.29	10.25	1.45	28.68	45.97	6.78	11.06	1.57	30.95	49.64
	Benton	8.09	7.55	9.14	1.20	25.59	48.43	8.18	9.95	1.31	27.81	52.75
	Average	8.03	6.08	10.23	1.51	26.55	47.60	6.59	11.12	1.65	28.87	51.77

TABLE I (Continued). PERCENTAGE COMPOSITION OF LEGUMES AND OTHER FORAGE CROPS.

		Calculations on air dry basis						Calculations on oven-dry basis				
Crop	Where grown County	Water	Ash	Crude protein N x 6¼	Ether extract	Carbohydrates		Ash	Crude protein N x 6¼	Ether extract	Carbohydrates	
						Crude fiber	Nitrogen-free extract				Crude fiber	Nitrogen-free extract
Clover alsike	Columbia	6.09	6.92	8.94	1.67	29.72	46.66	7.38	9.50	1.78	31.60	49.74
	Columbia	13.32	8.42	10.33	.77	29.05	38.11	9.66	11.92	.90	33.50	44.02
	Washington	6.70	5.34	11.12	1.67	29.18	45.99	5.79	11.94	1.79	31.23	49.25
	Linn	9.62	7.71	7.45	1.12	37.55	36.55	8.54	8.26	1.24	41.52	40.44
	Linn	10.56	6.29	9.84	1.23	35.44	36.64	7.03	11.00	1.38	39.65	40.94
	Linn	7.69	6.41	9.42	1.28	32.23	42.97	6.95	10.21	1.39	34.92	46.53
	Benton	5.92	6.85	9.56	1.13	26.50	50.04	7.44	10.19	1.20	28.18	52.99
	Benton	5.70	7.24	7.63	1.18	25.34	52.91	7.68	8.19	1.27	27.23	55.63
	Average	8.21	6.90	9.28	1.26	30.62	43.73	7.58	10.15	1.37	33.47	47.43
Vetch common	Columbia	6.72	6.98	14.75	1.10	26.95	43.50	7.52	15.82	1.18	28.90	46.58
	Columbia	7.53	5.49	15.07	.44	26.40	45.07	5.93	16.30	.50	28.52	48.75
	Columbia	8.36	6.87	13.44	1.25	31.80	38.28	7.50	14.68	1.36	34.69	41.77
	Washington	7.85	5.40	13.26	1.10	26.25	46.14	5.87	14.40	1.20	28.52	50.09
	Washington	7.98	6.77	15.80	1.20	25.72	42.53	7.34	17.50	1.30	27.96	45.90
	Linn	9.21	5.55	14.07	.98	26.88	43.31	5.86	15.00	1.08	29.60	48.46
	Linn	8.04	5.11	10.25	.81	24.76	51.03	5.56	11.15	.88	26.94	55.47
	Linn	8.50	5.67	14.06	1.22	29.42	41.13	6.20	15.37	1.33	32.18	44.92
	Linn	8.02	6.34	11.88	.90	27.65	45.21	6.90	12.95	.98	30.04	49.13
	Linn	7.80	6.07	13.87	1.01	26.00	45.25	6.59	15.05	1.10	28.21	49.05
	Linn	7.14	7.98	15.75	.92	25.75	42.46	8.59	16.98	.99	27.73	45.71
	Linn	6.69	7.23	11.20	.94	32.42	41.52	7.75	12.00	1.01	34.73	44.52
	Linn	7.50	7.26	13.56	.56	26.32	44.80	7.84	14.66	.60	28.43	48.47
	Benton	10.63	5.47	11.62	1.10	23.31	47.87	6.06	12.88	1.23	26.10	53.73
	Benton	12.20	4.97	12.12	1.10	23.95	45.66	5.66	13.56	1.25	27.20	52.33
	Benton	10.87	5.80	12.88	1.15	23.61	45.69	6.50	13.31	1.29	26.16	52.74
	Benton	8.60	5.45	14.63	.85	23.42	47.05	5.95	16.00	.93	25.62	51.50
	Benton	9.62	6.48	13.62	1.15	23.57	45.56	7.16	15.07	1.27	26.05	50.45
	Benton	8.73	5.55	12.12	.80	26.97	45.83	6.09	12.94	.88	29.52	50.57
	Benton	7.61	6.67	13.06	1.12	22.24	49.30	7.14	14.00	1.22	24.05	53.59
	Benton	8.81	6.01	13.56	1.01	25.19	45.42	6.62	14.87	1.11	27.60	49.80
	Benton	9.84	5.57	14.25	.88	24.74	44.54	6.20	15.88	.98	27.42	49.51
	Benton	7.73	5.52	12.52	.90	23.97	49.36	6.10	14.20	.98	25.98	52.74

	Benton	7.05	6.45	11.13	1.25	24.19	49.93	6.83	11.75	1.34	26.00	54.08
	Benton	8.89	5.82	13.12	1.17	24.50	46.50	6.38	13.87	1.28	26.88	51.59
	Benton	8.65	6.18	14.50	1.14	24.33	45.20	6.78	15.26	1.25	26.60	50.11
	Benton	8.12	5.64	13.12	.78	23.95	48.39	6.01	14.00	.85	26.06	53.08
	Benton	8.33	5.99	13.12	1.13	26.43	45.00	6.50	14.25	1.23	28.89	49.15
	Benton	8.84	7.26	12.87	.73	25.08	45.22	7.96	14.10	.79	27.45	49.70
	Benton	8.08	5.68	10.43	.98	22.45	52.38	6.18	11.34	1.07	24.44	56.97
	Benton	6.93	5.47	11.44	.88	28.15	47.13	5.86	12.29	.95	30.24	50.66
	Benton	7.63	5.01	14.00	.87	25.15	47.34	5.48	15.15	.94	27.21	51.22
	Benton	7.70	6.70	15.50	1.08	26.65	42.37	7.26	16.80	1.17	28.87	45.90
	Benton	7.71	7.76	13.30	.63	29.14	41.46	8.41	14.43	.68	31.55	44.93
	Benton	8.81	5.40	14.12	.92	25.95	44.80	5.82	15.49	1.01	28.46	49.22
	Average	8.36	6.10	13.26	.97	25.80	45.51	6.64	14.38	1.06	28.14	49.78
Vetch												
Woolly Podded	Benton	7.06	6.12	12.31	.73	24.44	49.34	6.60	13.28	.79	26.29	53.04
(Hairy)	Benton	7.05	6.30	12.62	.83	25.88	47.32	6.78	13.58	.88	27.85	50.91
(Purple)	Benton	7.65	5.02	13.26	.71	25.39	47.97	5.45	14.37	.77	27.50	51.91
Hungarian	Benton	9.08	7.52	14.40	1.80	29.00	38.20	8.27	15.85	1.98	31.97	41.93
Peas												
Canada field	Columbia	7.27	7.17	13.90	1.85	22.30	47.51	7.78	14.94	1.99	24.04	51.25
	Benton	8.32	5.54	13.74	.90	18.48	53.02	6.01	15.00	.98	20.16	57.85
	Average	7.80	6.35	13.82	1.31	20.39	50.27	6.90	14.97	1.48	22.10	54.55
Peas												
Tangier	Benton	7.30	7.49	10.12	1.10	26.75	47.24	8.05	10.94	1.19	28.82	51.00
	Benton	7.52	7.09	11.80	1.02	27.76	44.81	7.65	12.76	1.10	29.97	48.52
	Average	7.41	7.29	10.96	1.06	27.25	46.03	7.85	11.85	1.14	29.40	49.76
White clover	Columbia	8.91	7.70	10.82	1.79	24.56	46.22	8.45	11.88	1.96	26.97	50.74
White clover	Benton	10.41	8.48	13.92	1.03	20.00	46.16	9.45	15.53	1.15	22.34	51.53
	Average	9.66	8.09	12.37	1.41	22.28	46.19	8.95	13.70	1.56	24.65	51.14
Sweet clover	Benton	8.17	5.30	7.75	1.10	32.65	45.03	5.77	8.45	1.20	35.55	49.03
Eureka	Benton	7.53	5.39	9.95	1.12	31.24	44.77	5.83	10.75	1.21	33.77	48.44

TABLE I (Continued). PERCENTAGE COMPOSITION OF LEGUMES AND OTHER FORAGE CROPS.

		Calculations on air dry basis						Calculations on oven-dry basis				
						Carbohydrates					Carbohydrates	
Crop	Where grown County	Water	Ash	Crude protein N x 6¼	Ether extract	Crude fiber	Nitrogen-free extract	Ash	Crude protein N x 6¼	Ether extract	Crude fiber	Nitrogen-free extract
Horse bean	Benton	8.54	5.49	13.42	.84	21.96	49.75	6.00	14.68	.92	24.03	54.37
Wild peas	Benton	7.29	4.46	15.74	1.35	35.50	35.66	4.82	16.98	1.46	38.34	38.40
Rye grass	Columbia	8.40	5.57	5.62	1.15	29.20	50.06	6.08	6.13	1.26	31.87	54.66
	Linn	8.37	6.80	3.21	1.16	32.36	48.10	7.43	4.00	1.26	35.22	52.09
	Benton	7.82	5.51	4.19	.75	30.05	51.68	5.97	4.55	.81	32.54	56.13
	Average	8.20	5.96	4.34	1.02	30.54	49.94	6.49	4.89	1.11	33.21	54.30
Mesquite	Columbia	7.71	4.87	6.16	1.64	32.22	47.40	5.28	6.69	1.78	34.92	51.33
	Linn	7.72	5.85	3.83	1.56	30.52	50.52	6.35	4.15	1.69	33.08	54.73
	Benton	8.37	6.62	7.25	1.34	32.41	44.01	7.22	7.90	1.46	35.39	48.03
	Average	7.93	5.78	5.75	1.51	31.72	47.31	6.28	6.24	1.64	34.46	51.38
Timothy	Columbia	7.32	4.59	6.29	1.30	34.20	46.30	4.95	6.78	1.40	36.93	49.94
	Benton	7.08	4.09	4.87	1.01	34.42	48.53	4.41	5.19	1.09	37.04	52.27
	Benton	6.73	4.57	6.06	1.67	35.95	45.02	4.91	6.50	1.79	38.50	48.30
	Average	7.04	4.42	5.74	1.33	34.86	46.61	4.76	6.15	1.43	37.49	50.17
Orchard grass	Columbia	6.95	5.02	5.29	1.02	37.28	44.44	5.39	5.68	1.09	39.00	48.84
Orchard grass	Benton	7.91	4.41	3.85	.94	34.69	48.20	4.79	4.18	1.02	37.67	52.34
	Average	7.43	4.71	4.57	.98	35.98	46.33	5.09	4.93	1.05	38.34	50.59
Brome grass	Columbia	8.14	3.84	5.81	.85	31.06	50.30	4.18	6.33	.92	33.83	54.74
Millet	Columbia	8.21	8.42	9.89	1.06	29.82	42.60	9.18	10.77	1.15	32.51	46.39
Soft chess	Columbia	7.76	3.57	5.94	.91	33.11	48.71	3.87	6.44	.99	35.90	52.80

Redtop	Linn	7.53	6.40	3.12	1.08	37.81	44.06	6.93	3.37	1.17	40.94	47.59
	Linn	8.65	8.40	5.06	1.24	31.37	45.28	9.20	5.55	1.36	34.39	49.50
	Average	8.09	7.40	4.09	1.16	34.59	44.67	8.06	4.47	1.26	37.67	48.54
Fescue meadow	Benton	7.24	4.15	4.72	.90	31.41	51.58	4.48	5.10	.97	33.91	55.54
Oat grass Tall	Columbia	7.66	4.53	4.89	1.04	37.00	44.88	4.91	5.30	1.13	40.05	48.61
	Benton	7.31	4.99	4.66	1.35	32.52	49.17	5.38	5.03	1.46	35.13	53.00
	Average	7.49	4.76	4.78	1.19	34.76	47.02	5.15	5.16	1.30	37.59	50.80
Cheat	Benton	8.65	6.40	5.19	1.33	36.66	41.77	7.00	5.68	1.46	40.15	45.71
Meadow Fox Tail	Benton	7.62	7.72	5.72	1.75	29.34	47.85	8.36	6.20	1.89	31.73	51.82
Harding Grass	Benton	6.79	6.78	6.56	1.58	32.79	45.50	7.28	7.05	1.69	35.16	48.82
Beardless Rye	Benton	6.10	3.89	4.17	1.38	31.85	52.61	4.15	4.45	1.47	33.97	55.96
Vicia	Benton	7.98	7.51	19.64	1.38	25.91	37.58	8.15	21.24	1.50	28.21	40.90
Creeping Bent	Benton	6.38	5.76	6.05	1.87	28.02	51.92	6.15	6.47	2.00	29.91	55.47
Reed Canary	Benton	7.12	4.79	4.85	1.06	27.20	54.98	5.16	5.22	1.14	29.27	59.21
Reed Fescue	Benton	7.20	6.63	5.81	1.22	38.85	40.29	7.15	6.27	1.31	41.88	43.39
Lotus Crassifolius	Benton	8.43	8.05	18.94	1.54	22.64	40.40	8.78	20.68	1.68	24.73	44.13
Sunflowers	Columbia	9.16	10.17	9.89	2.68	25.34	42.76	11.20	10.89	2.96	27.89	47.06
Corn	Benton	9.44	5.47	9.80	1.39	23.16	50.74	6.04	10.73	1.53	25.59	56.11
Silages												
Corn	Benton	76.38	1.30	1.89	.42	6.08	13.93	5.52	8.01	1.76	25.72	58.99
	Benton	74.75	1.54	2.59	.69	4.73	15.70	6.09	10.28	2.73	18.75	62.15
	Benton	81.83	2.01	1.10	.26	5.23	9.57	11.06	6.08	1.45	28.78	52.63
	Benton	73.00	1.39	2.64	.97	4.45	17.55	5.14	9.78	3.58	16.48	65.02
	Benton	89.92	.59	1.06	.30	2.18	5.95	5.89	10.51	3.04	21.63	58.93
	Average	79.18	1.37	1.85	.53	4.53	12.54	6.74	8.93	2.51	22.27	59.55
Sunflowers	Benton	81.34	2.15	1.87	1.35	5.58	7.71	11.53	10.10	7.22	29.92	41.23
	Benton	77.20	2.52	2.42	.55	5.63	11.68	11.04	10.59	2.40	24.70	51.27
	Benton	84.80	1.59	1.83	.62	3.71	7.45	10.45	12.06	4.11	24.40	48.98
	Benton	81.25	1.65	1.36	.92	5.22	9.60	8.78	7.26	4.91	27.86	51.19
	Benton	77.62	1.55	2.24	.85	6.22	11.52	6.93	10.00	3.80	27.80	51.47
	Benton	86.70	2.04	2.12	.31	4.07	4.76	15.37	15.92	2.26	30.57	35.88
	Average	81.48	1.92	1.97	.77	5.07	8.79	10.68	10.99	4.12	27.54	46.67

TABLE I (Continued). PERCENTAGE COMPOSITION OF LEGUMES AND OTHER FORAGE CROPS.

Crop	Where grown County	Calculations on air dry basis						Calculations on oven-dry basis				
		Water	Ash	Crude protein N x 6¼	Ether extract	Carbohydrates		Ash	Crude protein N x 6¼	Ether extract	Carbohydrates	
						Crude fiber	Nitrogen-free extract				Crude fiber	Nitrogen-free extract
Oats and vetch	Benton	70.29	2.20	2.09	.52	9.70	15.20	7.41	7.05	1.76	32.61	51.17
	Benton	76.87	1.64	2.20	.68	7.99	10.62	7.08	9.50	2.94	34.61	45.87
	Average	73.58	1.92	2.14	.60	8.85	12.91	7.24	8.28	2.35	33.61	48.52
Horse beans	Benton	77.45	1.39	3.41	.67	6.25	10.83	6.15	15.13	2.95	27.73	48.04
	Benton	74.58	1.50	4.26	.34	7.20	12.12	5.92	16.74	1.33	28.38	47.63
	Average	76.02	1.44	3.84	.50	6.73	11.47	6.03	15.94	2.14	28.05	47.84
Barley and Vetch	Benton	70.15	1.96	2.97	.64	10.42	13.86	6.58	9.96	2.13	35.22	46.11
Corn and Clover straw	Benton	71.00	2.18	2.36	.55	8.80	15.11	7.52	8.15	1.88	30.38	52.07
Corn and Alfalfa	Benton	74.55	2.14	2.66	.68	4.56	15.41	8.41	10.44	2.67	17.90	60.58
Wheat	Benton	69.03	2.15	1.67	.69	10.87	15.59	6.96	5.38	2.23	35.08	50.34
Alfalfa	Benton	74.59	2.07	3.93	.96	8.47	9.98	8.14	15.47	3.79	33.35	39.25
Tangier peas	Benton	78.40	1.65	2.50	.53	7.51	7.41	7.62	11.56	2.43	34.77	43.62
Sweet Clover	Benton	70.45	1.79	2.70	.52	12.61	11.93	6.07	9.14	1.77	42.64	40.38
The Grains												
Wheat												
Huston	Benton	10.67	2.01	10.57	1.62	3.20	71.93	2.25	11.83	1.81	3.58	80.53
Marquis	Jackson	9.50	1.88	11.00	1.86	3.17	72.59	2.08	12.16	2.05	3.50	80.21
Baart	Jackson	10.16	1.89	11.52	1.26	2.81	72.36	2.11	12.84	1.40	3.13	80.52
	Average	10.11	1.93	11.03	1.58	3.06	72.29	2.15	12.28	1.75	3.40	80.42
Barley												
Fall	Linn	10.02	2.86	10.68	1.47	4.73	70.24	3.18	11.77	1.63	5.36	78.06
Bald	Benton	9.83	2.04	13.44	1.48	2.41	70.80	2.26	14.90	1.64	2.67	78.53
Hannchen	Benton	11.17	2.23	9.60	1.53	4.27	71.20	2.51	10.81	1.72	4.81	80.15
	Average	10.34	2.38	11.24	1.50	3.80	70.75	2.65	12.49	1.66	4.28	78.92

Oats												
Fall or Grey	Linn	9.38	3.58	9.95	5.28	9.97	61.84	3.95	10.98	5.82	11.00	68.25
White	Linn	9.58	3.31	10.32	3.80	13.05	59.94	3.67	11.47	4.22	14.44	66.21
Senator	Benton	9.22	3.46	9.69	4.11	12.47	61.05	3.82	10.66	4.53	13.73	67.26
Senator	Columbia	8.94	3.12	12.98	2.74	17.01	55.21	3.42	14.25	3.00	18.69	60.64
Black Victor	Lane	8.25	3.79	11.35	5.25	11.50	59.86	4.13	12.37	5.72	12.52	65.26
	Average	9.07	3.45	10.86	4.24	12.80	59.58	3.80	11.95	4.66	14.07	65.52
Miscellaneous												
Cheat seed	Benton	12.24	4.28	7.05	1.20	8.32	66.91	4.87	8.03	1.37	9.48	76.25
Sunflower seed	Benton	4.78	2.61	15.41	28.66	30.74	17.80	2.74	16.19	30.09	32.28	18.70
Southern Oregon Section												
Alfalfa	Josephine	7.22	7.70	15.30	1.30	30.15	38.33	8.39	16.50	1.40	32.50	41.21
	Jackson	6.62	6.43	14.06	1.58	27.22	44.09	6.88	15.07	1.69	29.13	47.23
	Jackson	6.34	5.21	13.86	1.52	37.33	35.74	5.56	14.82	1.62	39.84	38.16
	Jackson	6.22	9.48	12.62	1.37	31.39	38.92	10.06	13.44	1.46	33.46	41.58
	Jackson	6.94	8.52	15.00	.87	32.34	36.33	9.15	16.13	.94	34.74	39.04
	Average	6.67	7.47	14.17	1.33	31.68	38.68	8.01	15.20	1.42	33.93	41.44
Clover, red	Josephine	7.90	6.76	12.89	2.03	25.89	44.53	7.35	14.00	2.20	28.12	48.33
	Jackson	7.00	5.94	12.82	2.38	25.22	46.64	6.37	13.75	2.56	27.12	50.20
	Jackson	6.98	6.94	12.68	1.90	27.52	43.97	7.41	13.63	2.04	29.85	47.07
	Average	7.29	6.55	12.79	2.10	26.21	45.06	7.04	13.79	2.27	28.37	48.53
Clover, alsike	Jackson	6.24	6.17	10.06	1.80	29.21	46.52	6.61	10.75	1.92	31.16	49.56
Coast Section												
Clover, red	Tillamook	6.64	7.37	12.25	1.76	30.04	41.94	7.85	13.13	1.88	32.18	44.96
	Tillamook	6.27	8.32	12.37	1.69	30.76	40.59	8.94	13.19	1.80	32.80	43.27
	Average	6.46	7.84	12.31	1.73	30.40	41.26	8.39	13.16	1.84	32.49	44.12
Clover, alsike	Clatsop	6.21	6.46	13.50	1.56	27.39	44.88	6.89	14.37	1.66	29.20	47.88
	Clatsop	7.70	6.28	13.61	1.25	27.58	43.58	6.75	14.75	1.35	29.88	47.27
	Tillamook	6.78	7.16	9.50	1.16	33.54	41.86	7.55	10.19	1.24	35.97	45.05
	Tillamook	7.24	9.60	10.62	1.52	33.81	37.21	10.35	11.44	1.64	36.44	40.13
	Average	6.99	7.36	11.82	1.37	30.58	41.88	7.89	12.69	1.47	32.87	45.08

TABLE I (Continued). PERCENTAGE COMPOSITION OF LEGUMES AND OTHER FORAGE CROPS.

Crop	Where grown County	Calculations on air dry basis						Calculations on oven-dry basis				
		Water	Ash	Crude protein N x 6¼	Ether extract	Carbohydrates		Ash	Crude protein N x 6¼	Ether extract	Carbohydrates	
						Crude fiber	Nitrogen-free extract				Crude fiber	Nitrogen-free extract
Vetch												
common	Tillamook	7.36	6.98	14.07	.72	33.00	37.87	7.54	15.18	.78	35.62	40.88
Peas												
Canada field	Tillamook	9.49	4.81	13.98	1.08	23.64	47.00	5.14	16.38	1.19	26.13	51.16
Miscellaneous												
Yellow clover	Tillamook	8.50	5.24	10.82	1.61	31.69	42.14	5.73	12.50	1.76	34.64	45.37
Marsh land clover	Coos	9.97	9.00	14.41	1.91	26.65	38.06	10.00	16.01	2.12	29.60	42.27
Marsh land grass	Coos	6.78	4.87	4.60	.93	45.37	37.45	5.23	4.94	1.00	48.54	40.29
Canary grass	Coos	6.61	5.79	5.80	.85	31.95	49.00	6.20	6.21	.90	34.06	52.63
Sweet vernal grass	Coos	7.85	2.78	2.86	.79	34.00	51.02	3.02	3.10	.85	36.92	56.11
Salt grass	Coos	7.39	10.68	10.38	1.87	28.67	41.01	11.52	11.21	2.02	30.96	44.29
Redtop	Coos	8.13	5.73	7.62	2.12	26.94	49.46	6.24	8.29	2.31	29.33	53.83
Silages												
Corn*	Coos	72.64	1.81	4.57	.32	9.24	11.48	6.62	16.48	1.17	33.75	41.98
Sunflowers	Clatsop	83.38	1.58	1.95	.47	4.61	8.01	9.53	11.72	2.81	27.77	48.17
Horse beans	Clatsop	84.25	1.29	2.15	.61	3.80	7.90	8.18	13.65	3.86	24.13	50.18
Sunflowers and Pole Bean	Clatsop	82.38	1.57	1.83	.47	4.46	9.29	8.92	10.40	2.64	25.33	52.71
Oats and Peas	Clatsop	62.42	3.44	3.30	1.35	10.21	19.28	8.92	8.77	3.59	27.15	51.57

*Frosted.

TABLE II. THE CARBOHYDRATE FRACTION OF LEGUMES, FURTHER SEPARATION OF THE "NITROGEN-FREE EXTRACT." PERCENTAGE AVERAGES ON OVEN-DRY BASIS.

Legumes and number of determinations	Where grown	Crude fiber	Reducing sugars	Sucrose	Starch	Pentosans	Galactans	Not determined
Alfalfa (4)	Valley section	33.15	1.73	3.99	2.33	15.85	2.68	17.53
Alfalfa (5)	So. Oregon	33.83	1.14	4.48	3.26	15.35	2.17	15.04
Clover, red (9)	Valley section	26.65	5.14	6.22	2.25	14.11	2.22	24.07
Clover, red (2)	Coast section	32.49	2.91	1.58	1.40	14.75	2.64	20.84
Clover, red (3)	So. Oregon	27.93	3.20	4.07	2.42	13.83	2.96	22.05
Clover, alsike (3)	Valley section	30.02	4.33	3.87	3.58	14.73	2.98	22.05
Clover, alsike (4)	Coast section	32.87	2.64	2.26	3.25	15.78	4.47	16.68
Clover, alsike (1)	So. Oregon	31.16	3.17	3.08	1.13	15.85	2.60	23.73
Clover, yellow (1)	Coast section	34.64	5.46	.55	3.22	15.36	1.88	18.90
Vetch, common (15)	Valley section	27.08	3.31	6.29	6.35	15.33	1.67	18.04
Vetch, common (1)	Coast section	35.62	4.08	2.50	3.01	14.04	2.52	14.73
Peas, Canada field (2)	Valley section	22.10	1.06	4.70	11.53	12.30	1.61	23.33
Peas, Canada field (1)	Coast section	26.13	9.45	4.98	7.20	12.08	2.13	15.32
Peas, Tangier (1)	Valley section	28.82	2.38	5.51	7.25	15.58	2.21	20.07

TABLE III. AVERAGE WEIGHT IN POUNDS OF NUTRIENTS IN 100 POUNDS OF CROP AS ORDINARILY FED. CONDENSED FROM TABLE I.

Crop	Section	No. of analysis averaged	Water	Crude ash or mineral matter	Crude Protein N x 6¼	Ether extract "fat"	Carbohydrates	
							Crude fiber	N-free extract
Legumes								
Alfalfa	Valley	7	7.92	6.91	12.55	1.09	30.90	40.63
Alfalfa	Southern Oregon	5	6.67	7.47	14.17	1.33	31.68	38.68
Clover, red	Valley	19	8.03	6.08	10.23	1.51	26.55	47.60
Clover, red	Southern Oregon	3	7.29	6.55	12.79	2.10	26.21	45.06
Clover, red	Coast	2	6.46	7.84	12.31	1.73	30.40	41.26
Clover, alsike	Valley	8	8.21	6.90	9.28	1.26	30.62	43.73
Clover, alsike	Southern Oregon	1	6.24	6.17	10.06	1.80	29.21	46.52
Clover, alsike	Coast	4	6.99	7.36	11.82	1.37	30.58	41.88
Clover, white	Valley	2	9.66	8.09	12.37	1.41	22.28	46.19
Vetch common	Valley	35	8.36	6.10	13.26	.97	25.80	45.51
Vetch common	Coast	1	7.36	6.98	14.07	.72	33.00	37.87
Vetch, hairy	Valley	1	7.05	6.30	12.62	.83	25.88	47.32
Vetch Hungarian	Valley	1	9.08	7.52	14.40	1.80	29.00	38.20
Peas, Canada field	Valley	2	7.80	6.35	13.82	1.31	20.39	50.27
Peas, Canada field	Coast	1	9.49	4.81	13.98	1.08	23.64	47.00
Peas, Tangier	Valley	2	7.41	7.29	10.96	1.06	27.25	46.03
Peas, Wild	Valley	1	7.29	4.46	15.74	1.35	35.50	35.66
Non-Legumes								
Rye Grass	Valley	3	8.20	5.96	4.34	1.02	30.54	49.94
Mesquite	Valley	3	7.93	5.78	5.75	1.51	31.72	47.31
Timothy	Valley	3	7.04	4.42	5.74	1.33	34.86	46.61
Orchard grass	Valley	2	7.43	4.71	4.57	.98	35.98	46.33
Redtop	Valley	2	8.09	7.40	4.09	1.16	34.59	44.67
Redtop	Coast	1	8.13	5.73	7.62	2.12	26.94	49.46
Oat grass, tall	Valley	2	7.49	4.76	4.78	1.19	34.76	47.02
Corn, whole plant	Valley	1	9.44	5.47	9.80	1.39	23.16	50.74
Silages								
Corn	Valley	5	79.18	1.37	1.85	.53	4.53	12.54
Corn*	Coast	1	72.64	1.81	4.57	.32	9.24	11.48
Sunflower	Valley	5	81.52	1.87	1.99	.65	4.97	9.00
Sunflower	Coast	1	83.38	1.58	1.95	.47	4.61	8.01
Oats and Vetch	Valley	2	73.58	1.92	2.14	.60	8.85	12.91
Barley and Vetch	Valley	1	70.15	1.96	2.97	.64	10.42	13.86
Oats & peas	Coast	1	62.42	3.44	3.30	1.35	10.21	19.28
Horse Beans	Valley	2	76.02	1.44	3.84	.50	6.73	11.47
Horse Beans	Coast	1	84.25	1.29	2.15	.61	3.80	7.90
Grains								
Wheat	Valley	3	10.11	1.93	11.03	1.58	3.06	72.29
Oats	Valley	5	9.07	3.45	10.86	4.24	12.80	59.58
Barley	Valley	3	10.34	2.38	11.24	1.50	3.80	70.75

* Frosted.

TABLE IV. THE MINERAL CONSTITUENTS OF LEGUMES AND OTHER FORAGE CROPS OF WESTERN OREGON. FIGURES INDICATE PERCENT.

Crop	County	Water	Ash		Phosphorus			Calcium			Magnesium			Potassium			Sulfur	
			Air dry	Oven dry	Air dry	Oven dry	Ash	Air dry	Oven dry	Ash	Air dry	Oven dry	Ash	Air dry	Oven dry	Ash	Air dry	Oven dry
								Valley Section										
Alfalfa	Linn	6.70	6.67	7.15	.183	.197	3.02	1.47	1.59	22.08	.289	.309	4.33	1.09	1.16	16.30	.102	.109
	Benton	9.73	8.81	9.76	.279	.309	3.16	1.43	1.59	16.28	.176	.194	1.99	2.33	2.51	26.45	.303	.336
	Linn	7.62	6.94	7.50	.231	.260	3.33	1.06	1.15	15.30	.279	.302	4.03	1.75	1.89	25.22	.137	.148
	Columbia	6.25	6.00	6.40	.292	.311	4.87	.786	.819	12.82	.150	.160	2.50	1.80	1.92	30.06	.148	.158
	Linn	11.32	7.65	8.53	.230	.259	3.00	.920	1.04	12.02	.168	.189	2.19	2.15	2.42	28.10	.133	.150
	Linn	7.62	7.88	8.53	.162	.175	2.06	1.62	1.75	20.55	.197	.214	2.50	1.42	1.54	18.02	.126	.137
	Columbia	8.06	5.45	5.93	.173	.188	3.18	.800	.870	14.67	.074	.081	1.48	1.49	1.62	27.36	.077	.084
	Average	8.19	7.06	7.69	.221	.243	3.23	1.15	1.26	16.25	.190	.207	2.72	1.72	1.87	24.70	.147	.160
Clover, red	Benton	9.71	5.47	6.05	.131	.145	2.39	.868	.962	15.88	.236	.261	4.32	No determination			.098	.109
	Benton	8.38	5.92	6.46	.140	.152	2.36	1.44	1.57	24.13	.432	.472	7.30	1.15	1.26	19.44	.099	.108
	Linn	8.71	5.65	6.19	.170	.186	3.03	.878	.962	15.67	.257	.281	4.50	1.51	1.65	26.92	.103	.112
	Benton	7.97	6.44	7.00	.170	.184	2.63	.990	1.07	15.39	.215	.233	3.34	1.87	2.04	29.14	.126	.136
	Benton	8.02	5.40	5.87	.162	.176	2.99	.862	.937	15.95	.246	.258	4.56	1.47	1.60	27.30	.095	.104
	Linn	8.60	5.12	5.60	.138	.151	2.70	1.08	1.18	21.09	.337	.368	6.58	1.15	1.26	22.45	.068	.075
	Washington	7.56	6.42	6.95	.214	.232	3.34	.892	.965	13.90	.203	.220	3.17	2.03	2.19	31.50	.121	.131
	Benton	6.61	6.71	7.18	.143	.153	2.13	.892	.955	13.29	.211	.226	3.15	1.96	2.10	29.20	.089	.095
	Columbia	7.55	4.82	5.22	.115	.124	2.38	.984	1.06	20.41	.196	.212	4.08	1.36	1.47	28.14	.068	.074
	Benton	11.11	6.94	7.80	.195	.219	2.81	1.02	1.14	14.67	.148	.167	2.14	1.75	1.97	25.80	.085	.095
	Linn	7.85	6.37	6.91	.153	.166	2.52	1.21	1.31	19.00	.167	.181	2.62	1.19	1.29	18.70	.051	.055
	Benton	7.34	6.40	6.90	.161	.174	2.52	.780	.842	12.20	.139	.150	2.34	1.94	2.09	30.28	.067	.072
	Linn	6.98	6.32	6.79	.156	.168	2.47	1.08	1.16	17.10	.224	.240	3.54	1.29	1.39	20.40	.063	.068
	Benton	8.09	7.37	8.02	.166	.181	2.26	1.00	1.09	13.57	.165	.180	2.25	1.92	2.09	26.06	.085	.093
	Linn	8.56	6.36	6.96	.196	.214	3.08	1.00	1.10	15.80	.185	.202	2.91	1.57	1.72	24.68	.084	.092
	Columbia	8.85	5.75	6.31	.123	.135	2.14	.688	.755	11.97	.126	.138	2.19	1.75	1.92	30.50	.057	.063
	Average	8.24	6.09	6.64	.158	.173	2.61	.979	1.07	16.25	.218	.237	3.69	1.59	1.74	26.03	.085	.093
Clover, alsike	Benton	7.91	6.85	7.44	.150	.163	2.19	.996	1.08	14.53	.232	.252	3.39	1.99	2.16	29.00	.110	.120
	Washington	7.77	5.34	5.79	.233	.253	4.37	.752	.816	14.09	.234	.254	4.38	1.52	1.65	28.55	.143	.155
	Columbia	6.16	6.93	7.38	.196	.209	2.83	.804	.857	11.60	.207	.221	2.99	2.15	2.29	30.95	.090	.096
	Linn	10.56	6.42	7.18	.248	.277	3.86	.944	1.05	14.70	.170	.190	2.65	1.42	1.58	22.07	.102	.114
	Columbia	13.32	8.59	9.91	.188	.216	2.18	.610	.703	7.10	.116	.133	1.35	3.14	3.62	36.58	.073	.084
	Average	9.14	6.83	7.54	.203	.224	3.09	.821	.901	12.40	.192	.210	2.95	2.04	2.26	29.43	.104	.114

Vetch	Benton	9.83	5.47	6.06	.219	.243	4.00	.780	.865	14.25	.169	.187	3.08	1.39	1.55	25.48	.061	.067
	Benton	10.82	5.80	6.50	.184	.206	3.17	.952	1.07	16.38	.288	.323	4.96	1.08	1.21	18.60	.096	.108
	Benton	10.26	5.45	6.08	.210	.234	3.85	.868	.967	15.92	.216	.241	3.96	1.35	1.52	24.70	.098	.109
	Benton	6.58	6.67	7.14	.167	.179	2.51	.892	.955	13.40	.184	.197	2.77	1.89	2.03	28.40	.098	.105
	Benton	10.59	6.01	6.72	.266	.298	4.43	.832	.930	13.87	.240	.269	4.01	1.42	1.58	23.60	.091	.102
	Benton	10.22	5.57	6.20	.211	.237	3.79	.736	.819	13.20	.173	.192	3.10	1.43	1.60	25.72	.076	.085
	Benton	11.12	5.42	6.10	.187	.210	3.45	.700	.787	12.90	.230	.259	4.24	1.15	1.29	21.20	.110	.125
	Benton	5.42	6.45	6.83	.215	.227	3.33	.932	.986	14.45	.166	.175	2.57	1.69	1.79	26.28	.088	.093
	Linn	6.44	4.55	4.86	.131	.140	2.89	.548	.585	12.04	.126	.134	2.76	1.30	1.39	28.60	.062	.066
	Benton	6.11	5.64	6.01	.133	.142	2.36	.694	.738	12.30	.167	.178	2.96	1.50	1.60	26.60	.080	.086
	Benton	7.90	5.99	6.50	.309	.335	5.16	.690	.749	11.52	.190	.206	3.17	1.69	1.84	28.28	.089	.096
	Washington	6.26	5.40	5.76	.245	.251	4.54	.556	.593	10.30	.128	.136	2.36	1.78	1.90	32.95	.075	.080
	Washington	8.59	6.71	7.34	.310	.340	4.63	.564	.612	8.41	.187	.204	2.79	2.35	2.57	35.00	.128	.140
	Columbia	7.18	6.98	7.52	.281	.313	4.17	.812	.875	11.64	.176	.190	2.53	2.01	2.17	28.92	.089	.096
	Benton	8.84	7.07	7.76	.238	.260	3.36	.686	.753	9.70	.145	.159	2.05	1.78	1.95	25.20	.158	.173
	Benton	7.63	6.05	6.55	.136	.148	2.24	1.02	1.10	16.80	.216	.228	3.48	.958	1.04	15.83	.094	.102
	Linn	8.04	5.63	6.12	.246	.267	4.37	.668	.726	11.87	.158	.172	2.81	.743	.808	13.21	.080	.087
	Linn	8.50	6.90	7.56	.330	.360	4.68	.663	.725	9.61	.093	.102	1.36	1.39	1.52	20.13	.071	.078
	Linn	7.14	7.78	8.38	.273	.294	3.51	.832	.895	10.68	.097	.105	1.25	1.86	2.00	23.90	.069	.074
	Linn	7.50	7.26	7.85	.272	.294	3.75	.668	.721	10.88	.068	.074	1.06	1.68	1.81	23.12	.060	.065
	Linn	8.81	5.35	5.87	.262	.288	4.90	.538	.590	10.05	.109	.120	2.04	1.40	1.53	26.08	.042	.046
	Columbia	8.36	7.48	8.16	.257	.281	3.44	.532	.581	7.10	.128	.140	1.71	2.74	2.99	36.65	.105	.115
	Average	8.23	6.16	6.72	.231	.253	3.75	.735	.801	12.15	.166	.181	2.78	1.57	1.71	25.38	.087	.095
Peas	Benton	7.92	5.54	6.01	.236	.257	4.27	1.04	1.12	18.70	.207	.225	3.74	1.08	1.17	19.44	.081	.088
	Benton	7.52	7.05	7.62	.249	.270	3.54	.972	1.05	13.79	.150	.162	2.30	1.31	1.42	18.58	.101	.109
	Columbia	7.80	7.17	7.78	.243	.263	3.38	.880	.995	12.27	.195	.212	2.72	2.26	2.45	31.54	.102	.111
	Average	7.75	6.59	7.14	.243	.263	3.73	.964	1.04	14.92	.184	.200	2.92	1.55	1.68	23.19	.095	.103
Timothy	Benton	7.09	4.22	4.54	.104	.112	2.46	.074	.080	1.76	.035	.038	.828	.738	.795	17.50	.063	.068
	Benton	6.73	4.63	4.97	.155	.166	3.36	.076	.081	1.64	.033	.035	.708	1.37	1.47	29.55	.074	.079
	Columbia	7.32	4.65	5.02	.236	.254	5.07	.064	.069	1.38	.031	.034	.676	1.49	1.61	32.14	.072	.078
	Average	7.05	4.50	4.84	.165	.177	3.63	.071	.077	1.59	.033	.036	.737	1.20	1.29	26.40	.070	.075
Orchard grass	Benton	7.91	5.05	5.48	.141	.153	2.79	.076	.082	1.50	.048	.052	.950	1.72	1.86	33.05	.044	.048
Sunflowers	Columbia	9.16	9.76	10.66	.193	.213	1.98	.784	.863	8.04	.188	.207	1.93	3.70	4.07	37.90	.115	.127
Sunflower seed	Benton	4.78	2.57	2.70	.437	.459	17.00	.029	.030	1.12	.102	.107	3.82	.693	.728	25.96	.155	.162
Wheat	Benton	10.67	1.85	2.07	.342	.382	18.48	.0044	.0049	.238	.037	.042	2.03	.475	.532	25.68	.108	.121
Oats	Linn	9.38	3.60	3.97	.365	.403	10.15	.016	.0176	.445	.024	.027	.679	.434	.479	12.04	.113	.125
	Benton	9.22	3.49	3.84	.361	.398	10.34	.030	.033	.860	.034	.037	.975	.455	.500	13.00	.125	.137
	Columbia	8.94	3.07	3.30	.303	.333	9.88	.031	.034	1.02	.024	.027	.795	.463	.509	15.10	.166	.183

TABLE IV. (Continued). THE MINERAL CONSTITUENTS OF LEGUME AND OTHER FORAGE CROPS OF WESTERN OREGON.

Crop	County	Water	Ash		Phosphorus			Calcium			Magnesium			Potassium			Sulfur	
			Air dry	Oven dry	Air dry	Oven dry	Ash	Air dry	Oven dry	Ash	Air dry	Oven dry	Ash	Air dry	Oven dry	Ash	Air dry	Oven dry
	Lane	8.25	3.64	3.96	.408	.445	11.22	.026	.028	.714	.021	.023	.587	.418	.456	11.50	.136	.148
	Lane	10.10	3.01	3.35	.324	.360	10.77	.020	.022	.665	.028	.031	.942	.389	.432	12.92	.097	.108
	Average	9.18	3.36	3.68	.352	.388	10.47	.025	.027	.741	.026	.029	.796	.432	.475	12.91	.127	.140
Barley	Benton	11.17	2.13	2.40	.325	.366	15.24	.024	.027	1.15	.031	.035	1.47	.428	.482	20.12	.101	.114
	Benton	12.32	2.37	2.70	.347	.396	14.63	.013	.015	.540	.037	.042	1.57	.388	.442	16.50	.105	.120
	Average	11.75	2.25	2.55	.336	.381	14.94	.018	.021	.85	.034	.038	1.52	.408	.462	18.31	.103	.117
Corn	Linn	10.23	1.39	1.55	.314	.350	22.64	.022	.024	1.58	.029	.032	2.07	.318	.355	22.90	.109	.121
Coast Section																		
Clover, red	Tillamook	6.15	7.37	7.85	.161	.172	2.19	.980	1.04	13.29	.250	.267	3.40	2.35	2.51	31.90	.068	.072
	Tillamook	6.95	8.32	8.94	.165	.177	1.98	1.37	1.47	16.48	.247	.256	2.97	2.13	2.29	25.60	.106	.114
	Average	6.55	7.85	8.40	.163	.175	2.08	1.18	1.26	14.89	.249	.262	3.19	2.24	2.40	28.75	.087	.093
Clover, alsike	Clatsop	6.20	6.46	6.89	.167	.178	2.59	.620	.661	9.59	.403	.431	6.18	2.80	2.98	43.26	.112	.119
	Clastop	6.85	6.28	6.75	.171	.183	2.17	.612	.657	9.73	.402	.432	6.40	2.11	2.26	33.54	.073	.078
	Tillamook	5.95	7.10	7.55	.153	.163	2.15	.819	.872	11.54	.182	.194	2.56	2.65	2.81	37.20	No Det'n	
	Tillamook	7.28	9.60	10.35	.246	.256	2.57	.530	.570	5.50	.204	.220	2.13	3.38	3.64	35.20	.123	.133
	Average	6.57	7.36	7.86	.184	.195	2.37	.645	.690	9.09	.298	.319	4.32	2.74	2.92	37.30	.103	.110
Peas	Tillamook	6.37	4.81	5.14	.201	.214	4.17	.644	.688	13.38	.173	.184	3.59	1.45	1.55	30.08	.130	.139
Southern Oregon Section																		
Alfalfa	Jackson	6.48	6.43	6.48	.199	.213	3.10	1.22	1.30	18.93	.200	.213	3.10	1.42	1.51	21.98	.126	.134
	Josephine	8.22	7.70	8.39	.165	.180	2.15	1.04	1.14	13.56	.211	.230	2.74	2.26	2.46	29.35	.166	.180
	Jackson	6.33	5.21	5.56	.237	.254	4.55	1.62	1.72	30.99	.370	.394	7.08	.65	.69	12.43	.175	.187
	Jackson	6.87	8.52	9.15	.231	.248	2.71	1.16	1.24	13.61	.232	.249	2.73	2.41	2.59	28.32	.212	.227
	Average	6.97	6.97	7.40	.208	.224	3.13	1.26	1.35	19.27	.253	.271	3.91	1.69	1.81	23.02	.170	.182

Clover, red	Josephine	8.04	6.76	7.35	.133	.145	1.96	1.05	1.14	15.45	.300	.326	4.43	1.83	1.99	27.12	.123	.134
	Jackson	6.81	5.94	6.37	.195	.209	3.28	1.27	1.37	21.46	.264	.283	4.44	1.36	1.46	22.85	.151	.162
	Jackson	6.42	6.94	7.41	.238	.254	3.43	1.16	1.23	16.64	.292	.312	4.21	1.78	1.90	25.60	.119	.127
	Average	7.09	6.55	7.04	.189	.203	2.89	1.16	1.25	17.85	.285	.307	4.36	1.66	1.78	25.19	.131	.141
Clover, alsike	Jackson	6.66	6.17	6.61	.172	.184	2.78	.730	.782	11.82	.225	.242	3.65	1.91	2.05	31.02	.126	.135
Wheat	Jackson	9.50	1.89	2.09	.393	.434	20.80	.0064	.0071	.338	.0407	.045	2.15	.412	.455	21.80	.114	.126
	Jackson	10.16	1.85	2.06	.334	.372	18.07	.0048	.0053	.260	.0323	.0359	1.75	.477	.531	25.80	.122	.136
	Average	9.83	1.87	2.08	.364	.403	19.44	.0056	.0062	.299	.0365	.0405	1.95	.445	.493	23.80	.118	.131
Barley	Jackson	9.97	2.28	2.53	.396	.440	17.37	.0236	.0262	1.035	.0279	.031	1.17	.492	.547	21.37	.113	.126
	Jackson	9.83	1.97	2.18	.417	.453	21.20	.0216	.0239	1.096	.0231	.0256	1.175	.603	.659	30.60	.084	.093
	Average	9.90	2.13	2.36	.407	.447	19.29	.0226	.0251	1.065	.0255	.0283	1.172	.548	.603	25.99	.099	.110

TABLE V. WEIGHT OF CROP IN POUNDS REQUIRED TO EQUAL IN PROTEIN AND THE MINERAL ELEMENTS AMOUNTS OF THE SAME SUBSTANCES IN 100 POUNDS OF MILK. CALCULATED FROM ANALYTICAL DATA IN TABLES I AND IV.

Crop	Section	For protein N	For phosphorus P	For calcium Ca	For magnesium Mg	For potassium K	For sulfur S
Legumes							
Alfalfa	Valley	30	47	11	5	9	7
Alfalfa	Southern Oregon	27	49	10	4	9	6
Clover, red	Valley	37	65	13	4	9	13
Clover, red	Southern Oregon	30	55	11	3	9	8
Clover, red	Coast	31	63	11	3	6	13
Clover, alsike	Valley	41	50	16	5	7	11
alsike	Southern Oregon	38	60	18	4	8	9
alsike	Coast	32	56	20	3	5	11
Vetch, common	Valley	29	44	18	5	9	13
Peas, field	Valley	27	42	13	5	10	12
Peas, field	Coast	27	51	20	5	10	9
Non-legumes							
Timothy	Valley	66	62	182	27	12	16
Orchard grass	Valley	83	72	170	19	9	25
Grains							
Oats	Valley	35	29	516	35	35	9
Barley	Valley	34	31	716	26	36	11

* Grain only.

TABLE VI. FERTILIZING MATERIALS IN POUNDS REQUIRED TO REPLACE IN THE SOIL NITROGEN AND OTHER ESSENTIAL ELEMENTS USED IN THE PRODUCTION OF ONE TON OF AIR-DRY LEGUME OR OTHER FORAGE CROP.

Crop	Section	Sodium nitrate for nitrogen N	Super-phosphate for phosphorus P	Limestone for calcium Ca	Sulfate of potash for potassium K	Muriate of potash for potassium K	Land-plaster for sulfur S
Alfalfa	Valley	267	60	64	86	83	17
Alfalfa	Southern Oregon	302	56	70	85	81	19
Clover, red	Valley	218	43	54	80	77	10
Clover, red	Coast	263	44	66	112	108	10
Clover, red	Southern Oregon	273	51	64	83	80	15
Clover, alsike	Valley	197	55	46	102	98	12
Clover, alsike	Coast	252	50	36	137	132	12
Clover, alsike	Southern Oregon	215	46	41	96	92	14
Vetch, common	Valley	283	62	41	79	76	10
Peas, field	Valley	295	66	54	78	75	11
Peas, field	Coast	299	54	36	73	70	15
Timothy	Valley	123	45	4	60	58	8
Orchard grass	Valley	97	38	4	86	83	5
Sunflowers	Valley	211	52	44	185	178	13
Wheat *	Valley	235	93	.2	24	23	12
Wheat *	Southern Oregon	......	98	.3	22	21	13
Oats *	Valley	232	95	2	21	20	14
Barley *	Valley	241	91	1	20	19	12
Barley *	Southern Oregon	221	110	1	27	26	11
Corn *	Valley	......	85	1	16	15	12

*Grain only.

Station Bulletin 198 August, 1923

Oregon Agricultural College

Experiment Station

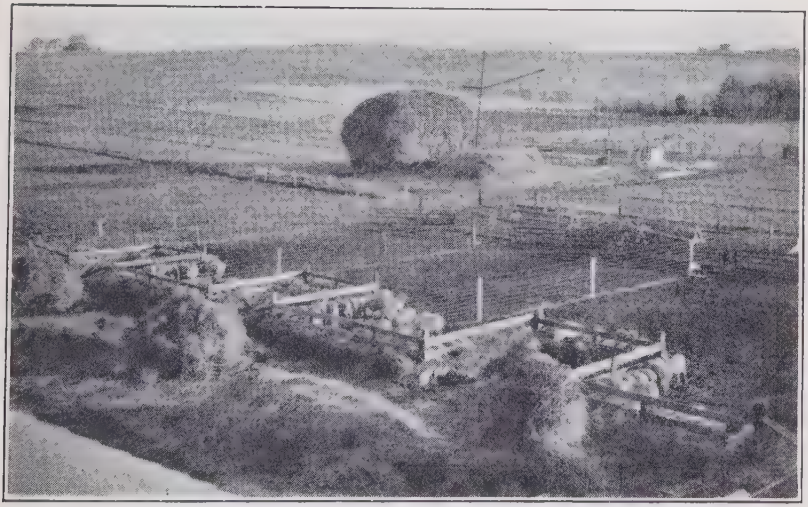
Fattening Lambs on Alfalfa

By

E. L. POTTER

and

H. K. DEAN



Lambs fed in the open at the Umatilla Experiment Station, 1922-23, made rapid and economical gains.

CORVALLIS, OREGON

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SUMMARY

The ideal feeder lamb is a thrifty, healthy lamb, weighing not less than fifty and not more than sixty pounds.

Good thrifty lambs will gain one-third pound per day and will be fat in from forty to ninety days.

It requires three hundred pounds of grain and nine hundred pounds of alfalfa to put on one hundred pounds of gain with fattening lambs.

The standard ration on the alfalfa farms is one pound of whole grain and three pounds of alfalfa.

One ton of grain is worth three tons of hay for fattening purposes.

Lambs may be fattened on as little as three-fourths pound of grain per day, when grain is expensive, or as much as one and one-half pounds per day when grain is cheap.

Barley, wheat, oats, corn, or any mixture of these, are good for fattening lambs.

Grains are best fed without grinding and hay without chopping.

Silage has a feeding value of from forty to seventy percent that of good alfalfa hay, depending upon the kind and quality of the silage.

The cost of shipping to Portland is $0.75 to $1.25 per one hundred pounds.

The average increase in price of lambs on the Portland market during the winter season is forty-three cents a month.

The normal margin in fattening lambs, including improvement in quality of the lambs and raise in the winter market, is one dollar to three dollars per hundred pounds.

Fattening Lambs on Alfalfa

By

E. L. POTTER and H. K. DEAN

INTRODUCTION

This bulletin is aimed to give to the alfalfa raisers of Eastern Oregon the essential facts of the lamb fattening industry as conducted on the farms in that section of the state. It is especially our object to show what can be reasonably expected of lamb fattening as a means of marketing surplus alfalfa hay and the manner in which the largest possible amount of alfalfa hay may be utilized in the most efficient manner. It is not the object of this bulletin to boost or to discourage the lamb fattening industry, but rather to put in simple, condensed form the essential facts from which every alfalfa producer may base his own decisions.

This bulletin, however, does not apply to the big commercial lamb feeder in Portland and neighboring points, who is fattening lambs on a heavy feed of screenings or grain, and using a very limited amount of hay.

The facts given in this bulletin are based upon experiments conducted at the Experiment Stations at Hermiston and Union, and experimental data from other states, in so far as they may be applicable to Oregon conditions.

BUYING FEEDERS

The ideal feeder lamb is a thrifty lamb weighing about 55 pounds, smooth and blocky in his conformation, and carrying a good deal of black-faced blood. In actual practice this ideal is not always obtainable, but the first two points, of thrift and proper size, are absolutely essential. One can sometimes get satisfactory results on lambs of poor conformation and breeding providing the lambs are thrifty and of the right size and bought at the right price; but lambs that are puny, stunted, wormy, and diseased are not worth feeding. Since feeder lambs are often those left after the fat lambs have been taken out of the flock the buyer of feeders cannot be too cautious. Good feeder lambs must also be small enough, so that they can be made fat before they weigh more than eighty pounds. Fat lambs weighing over eighty pounds will not bring as good a price as the smaller lambs and when they get up to ninety or one hundred pounds the cut in price is usually very heavy, regardless of their condition or quality. Since it usually takes twenty to twenty-five pounds of gain to make the lamb fat it will be seen that he must not weigh over sixty pounds at the start, unless he is already half fat. On the other hand, it is possible for a lamb to be so small that it will take too long and too expensive a feeding period to put him in market condition. It is generally considered that fifty pounds is about the minimum size for good feeder lambs, but if the lambs are thrifty, those as small as forty pounds may be fattened successfully. At the Umatilla Branch Experiment Station, last winter, fifteen lambs were culled out of a bunch of two hundred and fed separately. They seemed reasonably thrifty, but lacked breeding and quality, and weighed only 41 pounds at the start. They gained .31 pound per head per day, while the better lot from which these were culled weighed 49 pounds at the start and gained .33 pound per head per day on the same kind of feed. While the small lambs fattened more satisfactorily than was expected, the larger lambs required nine percent less feed per pound of gain and were better lambs when finished. It was estimated that they were worth, when finished, sixty-seven cents per hundred pounds more than the cull lot. Considering all these differences when the good lambs cost ten cents per pound at the start the cull lambs should have been bought for 8¼ cents. Our conclusions, therefore, were that lambs as small as forty pounds could be fattened satisfactorily, but that they should be purchased at a considerably reduced price.

On the other hand, some of the exceptionally large lambs fed at the Experiment Station at Union have sold at a discount on account of their large size, in spite of the fact that they were very choice in quality, breeding, and condition.

When lambs come in from the range in the fall those that weigh seventy pounds, or over, are, or should be, fat enough for slaughter. The smaller lambs will be cut back and used for winter feeding, while those that are very small and weigh less than fifty pounds are usually held over and marketed as yearlings. Lambs of good black-faced breeding that were lambed on hay before the grass season, and have been on reasonably good range will be fat enough for slaughter, and it will be only the less thrifty ones that will be cut back for feeding purposes. Lambs that were lambed on grass, instead of very early on hay, will in most cases, have a much smaller proportion of fat lambs in the fall and a higher proportion of feeders. The feeders will, also, be of better quality. Lambs that have been dropped late and that contain a high percentage of Merino blood will practically all be feeders, except those that are too small for feeding purposes and have to be carried over as yearlings. Late lambs and lambs from districts of scanty feed usually make good feeders, but an early lamb that has had good feed all summer and is still not ready for slaughter, very likely has something wrong with him.

A lamb of black-faced or long-wooled breeding is usually to be preferred when other things are equal, but the other things are not always equal and the top of a bunch of fine-wooled lambs will commonly be more satisfactory in the feed lot than the cut-backs from a black-faced band. In the matter of breeding, therefore, the buyer must often compromise between what he would like and what he can get. In the matter of weight and thrift, however, he can afford to make no compromises. If the lambs are unthrifty they will not gain, and if they are too large they will not sell. On the other hand, almost any thrifty lamb weighing around 55 pounds can be made into a market topper in sixty to ninety days. Condition is also an item in determining the price. A lamb that already carries a good deal of fat can be finished in less time and with less expense than one that is very thin, and he will, therefore, command a higher price.

In buying lambs it should be remembered that while a standard-size double-deck car will accommodate three hundred or more feeder lambs, it will not take care of them after they are fat. Two hundred and fifty in a car will be plenty then, and if exceptionally heavy and carrying a large amount of wool, two hundred may be enough. In weight the average car will carry 20,000 to 22,500 pounds.

Before lambs go into the feed lot they should be thoroughly examined by a veterinarian or competent sheep-man and if not free from ticks, scab, lip and leg ulceration, and other troubles, should be dipped and given such other treatment as may be necessary. Feeding ticky or diseased lambs is a waste of feed.

EQUIPMENT

Feed yards for lambs must necessarily be located on reasonably dry, well drained ground, and in most cases, must be fenced dog tight. If they can be located where well protected from severe winds and storms so much the better. It will not ordinarily, however, be necessary to provide barns or sheds. In three tests at Union it was found that there was very little difference between feeding lambs in the open and giving them access to a good shed. A shelter shed 16x50 feet in dimensions, returned a profit of $31.50 for three years' use, which would offer no profit over interest and depreciation.

The lambs used the shelter freely during wet, stormy weather, but were indifferent to it during cold dry weather. The lambs fed in the open, without shelter, made rapid and economical gains, and were well finished at the end of the tests. (See Oregon Station Bulletin 175.)

Twelve to fifteen square feet of lot room, exclusive of feed racks and troughs, is sufficient, although most lots are made three or four times this large. Exclusively large lots are not only unnecessary, but are hard to keep clean, and much of the manure is wasted.

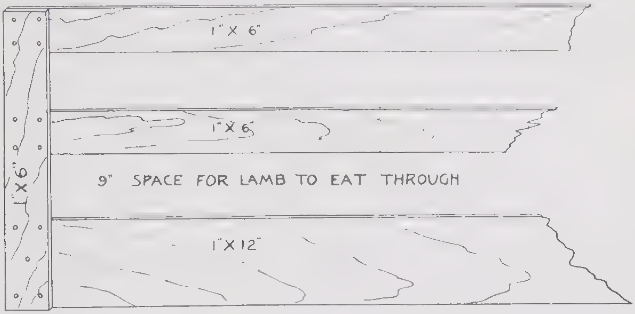


FIG. 1 PANEL FOR FEEDING ALFALFA TO FATTENING LAMBS.

Where alfalfa is the chief feed the most popular method of feeding the hay is by an arrangement of panels set at right angles to each other, as is shown on the cover. These panels are made of one-by-six fence boards with a twelve-inch board at the bottom. The second board is nine inches above the bottom board, and the lambs feed by putting their heads through this nine-inch space. A third and even fourth board are added to give the panel the desired height. (See Fig. 1.) The hay is placed in piles outside of the lot and small quantities pushed up to the panels three or four times a day. Lambs will not eat large quantities of hay if given fresh hay only once a day. The amount of panel space is usually estimated at one foot for each lamb, but on account of the space lost in the corners this is hardly enough and one should figure on about ten lambs to each twelve feet of panel.

The best grain trough is one about twelve inches wide, three to four inches deep, and placed twelve inches from the ground. It should also have a bar along the top to prevent the lambs from jumping into it. This kind of trough is strong and simple and may be turned over on its side for cleaning. (Fig. 2.) These troughs should be in a separate pen into which the lambs are turned after the feed has been distributed. About twelve inches of space on one side of the trough is required for each lamb. It is important to have about the right amount of trough room. If too much, the greedy lambs get a second helping; if not enough, the weak lambs will not get their share.

Plenty of good, clean water and salt must be provided so that the lambs can have easy access to them at all times. In very cold weather tank heaters placed in the water troughs are of great assistance in preventing freezing. Warm water, however, is not necessary. There is a lot of argument about water, but the essential thing is clean water where the lambs can walk up and take a drink at any time without wading in the mud or slipping on the ice. Creeks and ditches are seldom very satisfactory on account of the difficulty the lambs have in getting to them in muddy or icy weather.

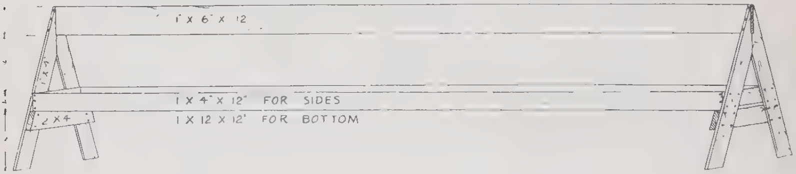


FIG 2 GRAIN TROUGH FOR FATTENING LAMBS

FEEDING

If proper feed trough space has been provided, lambs can be started on one-fourth pound of grain a day without the slightest danger. In two of our tests the lambs were started on oats and then changed to barley, but this did not seem necessary, as the lots started on barley never gave any trouble. When once started on grain, increases may be made at the rate of 1-10 pound per day. Grinding grain for fattening lambs is not advisable, although it may pay to both grind the grain and chop the hay for old ewes with broken mouths. Feed troughs should in all cases be turned over and cleaned every day. Lambs will not eat from dirty troughs. The grain must be very evenly distributed in the troughs before the lambs are turned in. If not evenly distributed, or if there is too much or too little trough room some lambs will get too much and others too little. The lambs must be fed at the same time each day as they are very sensitive to the least irregularity. If these simple precautions are followed to the letter the newest amateur should get good results: good gains and no lambs off feed.

LENGTH OF THE FEEDING PERIOD

Any lamb worth feeding and on good feed will be fat in ninety days and as large as the market will stand; while extra large, fleshy feeders will be ready for market in forty to fifty days. The large proportion of the lamb feeding is from sixty to eighty days. Of course, if the lambs are fed only hay for awhile, that time should not be counted, as the lambs do not fatten on hay alone. Lambs are often fed hay alone, or a very light ration of grain and hay, in order to hold them for a later market. This is done, however, with full knowledge of the fact that a better and cheaper finish may be made with a heavier feed.

HAY

On the farms of the Northwest, alfalfa is practically the only kind of hay used in fattening lambs and is likewise the only kind that should be used for that purpose. The use of a good legume hay is more important with lambs than with any other animal. To attempt to fatten lambs with wild hay, grain hay, or timothy would be a serious mistake wherever it is the object to feed as much hay and as little grain as possible.

The method of feeding hay has already been outlined. In some places the hay is chopped before being fed. If the hay is carefully handled it is probable that the cutting increases its value somewhat, although the tests on record have so far failed to show any real advantage from cutting or grinding, except for old ewes with bad teeth. The quality of the hay is, however, of considerable importance and hay that is bright and palatable will produce larger gains and save grain. In two years' tests the Irrigation Branch Station at Prosser, Washington, found that second cutting was a little less palatable and made slightly less daily gains than first or third cutting. In the final cost per pound gain, however, there was but very little difference. The difference between cuttings is doubtless largely a local question and depends greatly on the way the hay is put up and handled; but it is fairly safe to say that the first cutting is the best with the third very close behind. The second cutting is not quite as good as the other two, but may nevertheless be used for fattening purposes with entire satisfaction.

Amount of Hay. On the farms of Eastern Oregon, alfalfa is usually fed in just as large quantities as the lambs can be induced to eat. The skill of the feeder is often measured by the amount of hay he can get the lambs to eat. The amount fed will vary from two to four pounds, depending upon the size of the lambs, kind of hay, other feed, and weather conditions. With one pound of grain the hay fed per day will usually be about three pounds.

Waste Hay. All of the figures used in this bulletin are based upon the total amount of hay fed. Where the lambs are fed all the alfalfa hay they can be made to eat there will be a considerable proportion of stems and coarser hay that will be refused. This waste or refuse hay will average about twenty percent. It is often a temptation to force the lambs to eat up all this hay, but this is poor policy and usually results in unsatisfactory gains. This refused hay, while entirely unsuitable to lamb fattening does make a very satisfactory feed for wintering stock cattle or horses. Horses in the winter time will do splendidly on the hay cleaned out of the feed racks. For this purpose the refused hay may be considered to have a value of at least fifty percent of that of good hay.

KINDS OF GRAIN

Any of the common cereals, as well as screenings and other by-products, may be used for lamb feeding purposes. The feeds available to the farmer of the Northwest are chiefly barley, wheat, and oats, and corn in some years when the prices are right. Any one of these four, or any mixture of them, will give satisfaction for lamb fattening providing it be fed unground and in reasonable amounts, along with good alfalfa hay. In a test recently conducted by the Umatilla Branch Station at Hermiston comparing corn, wheat, barley, and oats the following results were obtained:

TABLE I. FEEDING CORN, WHEAT, OATS, AND BARLEY TO FATTENING LAMBS

	Lot 1 corn	Lot 2 wheat	Lot 3 oats	Lot 4 barley
Weight at beginning	52.4	51.5	52.1	48.9
Weight at close	88.6	86.0	85.0	82.0
Total gain	36.2	34.5	32.9	33.1
Daily gain	.366	.348	.332	.334
Hay offered—daily ration	3.32	3.19	2.92	3.00
Hay refused	.90	.81	.79	.83
Hay consumed	2.42	2.38	2.13	2.17
Grain	.95	.95	.95	.95
Feed per 100 pounds gain				
Hay	905	939	879	898
Grain	259	279	285	283

From this it will be seen that all four grains gave entire satisfaction. Comparing the other grains with barley we find that the corn was worth eight percent more, wheat three percent less, and oats practically the same. Other tests conducted at various places throughout the country indicate that on the average barley is probably worth ten to twelve percent less for lamb fattening than the number three corn, which we commonly get in the Northwest. If compared with a strictly high grade corn the difference would probably be twelve to fifteen percent. While wheat in this test proved sligthly less valuable than barley it has in most cases proved a better feed than barley and but very slightly inferior to corn. Oats are commonly looked upon as unsatisfactory for fattening purposes; yet they gave satisfactory results for fattening lambs. Tests conducted at other stations confirm our own tests and indicate that oats are similar in fattening value to barley. A mixture of grains, however is usually better than any one grain alone. The important fact shown in this test, however, is that all four grains, fed whole and in moderate amounts, together with all the alfalfa hay they would eat, gave good daily gains and produced a good finish. These results were fully as satisfactory as those obtained in the corn belt where the lambs were fed all the corn they would eat, together with a less palatable and nutritious hay. The choice of grains should therefore depend entirely upon the purchase price.

Amount of Grain. The amount of grain that may be satisfactorily fed to fattening lambs varies from ¾ pound per head per day, up to all that they will eat, which will be about 1½ pounds. If fed less than ¾ pound the lambs will not fatten readily and at the end of the feeding period will be found to have grown a little in size, but not to have improved in condition. Three-fourths pound will make them fat, although we usually recommend one pound. Whether to feed a larger amount than one pound will depend upon the relative price of hay and grain. We usually figure that one pound of grain is worth three pounds of hay and if the grain does not cost more than three times the price of hay it would be advisable to feed all the grain they would eat. The cost per hundred pounds would be about the same and the lambs having the larger amount of grain would probably sell a little better. Where the price of grain is as much, or more, than four times the price of hay it is best to limit the grain to not over one pound per day. In all cases the lambs should be started on a small amount of grain and worked up gradually; one-fourth pound per day is about right for the first day. As soon as all the lambs are eating, which is usually the first day, the amount of grain can be gradually increased at the rate of not over 1-10 pound per day until the ration reaches one pound. It can then be left at this figure for the remainder of the time. The grain is ordinarily fed in two feeds—one-half in the morning and one-half in the evening.

SILAGE

Silage has proved a very satisfactory feed for fattening lambs, but since it must be used as a substitute for hay rather than for grain, and since its use does not increase the daily gains or the finish of the lambs it has not given such phenomenal results with lambs as it has with fattening steers. Besides corn silage we have available, especially in the higher altitudes of Eastern Oregon, peas-and-bald-barley silage, and sunflower silage. These silages have been given careful tests through two or more years at the Eastern Oregon Branch Station, at Union, with the results shown below:

TABLE II. AVERAGE OF 1918-19 AND 1921-22 TESTS ON FEEDING PEAS-AND-BALD-BARLEY SILAGE TO FATTENING LAMBS

	Lot 1 alfalfa and barley	Lot 2 alfalfa, silage, and barley
Weight at beginning	82.1	81.9
Weight at close	102.7	103.6
Total gain	20.6	21.7
Daily gain	.266	.28
Alfalfa offered	2.29	1.96
Alfalfa refused	.33	.35
Alfalfa consumed	1.96	1.61
Barley	1.0	1.0
Silage	....	1.0
Feed per 100 pounds gain:		
Alfalfa offered	861	700
Barley	372	354
Silage	....	350

TABLE III. AVERAGE OF 1918-19 and 1921-22 TESTS ON FEEDING SUNFLOWER SILAGE TO FATTENING LAMBS

	Lot 1 alfalfa and barley	Lot 2 alfalfa, silage, and barley
Weight at beginning	73.7	73.8
Weight at close	93.7	94.3
Total gain	20.0	20.6
Daily gain	.246	.254
Alfalfa offered	2.4	2.14
Alfalfa refused	.32	.35
Alfalfa consumed	2.08	1.80
Barley	1.0	1.0
Silage	....	1.0
Feed per 100 pounds gain:		
Alfalfa offered	976	846
Barley	402	390
Silage	....	385

In these tests it will be seen that silage increased the gains only very slightly. One ton of peas-and-bald-barley silage replaced 1229 pounds of alfalfa hay, or in other words, had 61 percent of the feeding value of alfalfa. In the case of sunflower silage one ton of silage replaced 862 pounds of alfalfa hay, and had, therefore, 43 percent of the feeding value of the hay. Other tests indicate that corn silage of the variety commonly grown in the cool climates will have a value slightly less than peas-and-bald-barley silage; while corn silage grown in the lower altitudes where the grain is well matured, will have a feeding value somewhat higher. One ton of strictly first-class corn silage may be considered as having sixty to seventy percent of the value of one ton of good alfalfa hay. It will be understood, however, that silage from any crop varies greatly in feeding value, even when preserved. Silage with a lot of mature grain in it will have a high value, while silage made from immature, watery material will have a low value. On the basis of these figures the corn-belt farmer is justified in using as much silage as possible, but in Eastern Oregon where hay is so much easier grown than silage the growing of silage extensively for feeding lambs is not usually to be recommended.

Perhaps the chief reason why we do not need silage is that in alfalfa hay and the common Eastern Oregon cereals we already have a ration that can scarcely be improved.

MARKETING

Nearly all of the lambs fattened in Eastern Oregon and put on the market during the winter and early spring, are shipped to Portland; some are sold on the home ranch, but these, ordinarily, are bought by shippers who in turn send them to Portland. Where the lambs are sold at home and weighed out of the feed lot full of feed and water it is customary to dock the weight about four percent. In case the lambs are shipped to Portland they are given what feed and water they wish at the stock-yards and sold full without dockage. In spite of this, however, there is a heavy loss of weight between the home feed yard and the Portland market and this will generally range from about 4½ percent to 7 percent, based upon the full feed yard weight. The lambs fed at Hermiston last year shrank 4.4 percent. Lambs shipped during the last seven years from Union have shrunk from five to seven percent. As previously stated, where the lambs are sold at home it is usually customary to dock the weight four percent, so that the difference between the selling weight at Portland and the weight at which they would be sold at home will generally be from ½ to 3 percent.

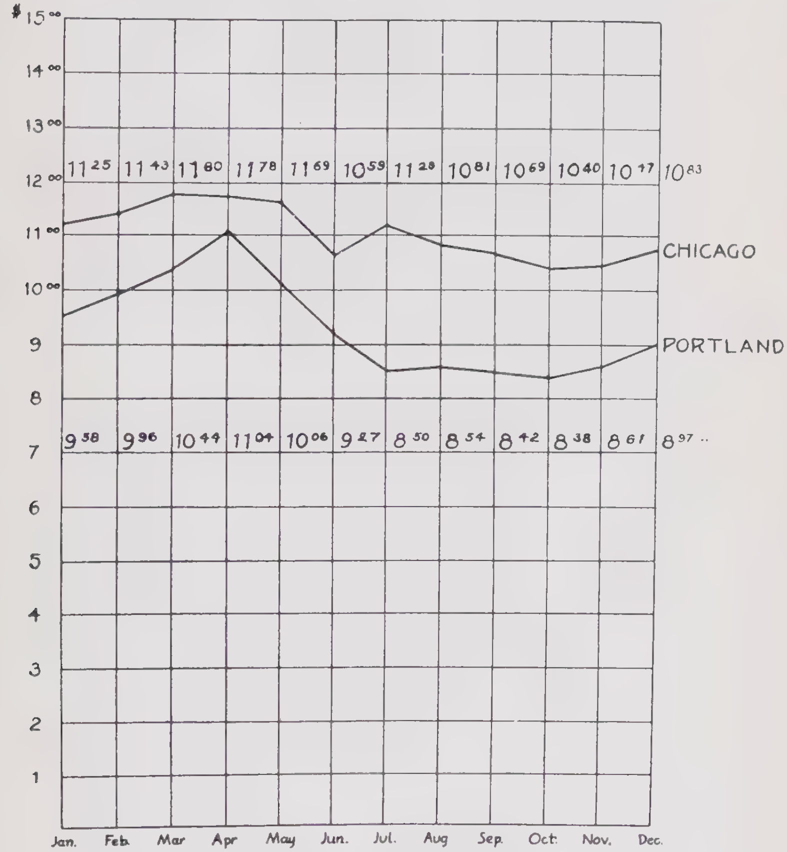
In addition to freight, the shipping expenses include commission, yardage, and feed in Portland, generally amounting to $45 to $50 a car-load, the expenses of a man to take care of the stock enroute, and the shrinkage. Lambs will have to sell at from $0.75 to $1.25 per hundred more in Portland than at home in order to cover the expenses of shipping. This is without allowing salary for the man in charge; if the latter is allowed, the margin will be somewhat greater. It is never possible to forecast exactly the expenses since the shrink will generally vary considerably without any apparent reason. A rough average, however, would be to figure the shrink on a two-hundred mile shipment at four to six percent of the full feed yard weight; and for three-hundred miles at five to seven percent. For longer shipments, such as to Missouri River markets or Chicago, the shrinkage will be about ten percent.

Top prices for lambs in Portland are usually not hard to obtain. Lambs that are fat enough to kill well and that are within the required weights will ordinarily bring the top price. Naturally, however, when lambs are scarce the buyers are less particular and when they are plentiful they are extremely particular.

The average monthly prices on lambs at Chicago and the average top prices on lambs at Portland are shown in the accompanying chart.

CHART I

Monthly Lamb Prices at Chicago and Portland
For twelve Years 1910 ~ 1922 Inclusive.
(Upper) Average of Monthly Chicago Lamb Prices.
(Lower) Average of Monthly Top Lamb Prices at Portland.



It will be noted that in Portland there is a normal tendency for lambs to increase in price from October to April. This increase has averaged through the past twelve years, 43 cents a month. It should be understood, however, that this average increase of 43 cents a month is only an average and that in reality there have been many exceptions. We would assume that during the three months winter period, from November to February, the price of lambs would improve $1.39 a hundred pounds. The actual difference, as nearly as the figures can be estimated for the past few winters, is as follows: 1914-15, $1.62; 1915-16, $1.38; 1916-17, $1.12; 1917--18, $0.75; 1918-19, $1.87; 1919-20, $5.50; 1920-21, $0.75 decrease; 1921-22, $3.87; 1922-23, $1.87. The year 1920-21 was peculiarly treacherous. The lambs fattened and marketed early made a fair profit, while those marketed late stood tremendous losses. During the month of February when lambs ordinarily are expected to increase in price the price went down $3.00. The next year, however, was remarkable in the other way and many lambs were put on feed at 5c and 6c and sold at 12c.

The lambs usually have to come off the grass in November and if put on feed at that time would be ready for market in February. The market chart indicates, however, that April is ordinarily the best month in which to market fat lambs. As a general rule, fat lambs held until the late market cost enough more to about offset the additional price. It will be noted that the spread between Portland and Chicago prices is greatest in the summer and least in the late winter and early spring, which, of course, accounts for the fact that during the summer Oregon ships most of her lambs East, while in the winter most of them go West.

FINANCIAL DISCUSSION

The question of profit or loss is always the most vital one to the stockman or feeder. The fluctuation in the market during the time the lambs are on feed will always be the most important factor in determining the profit or loss of the feeding operation. In addition to fluctuations in the market there will always be some variations in the quality of the feed, the weather, and the feeding quality of the lambs. When we take a considerable number of lambs through a period of years, however, we find that we can forecast very accurately the amount of feed needed and the gains that will be made. Therefore, if we know the price of the feed and the price of the feeder lamb, we can forecast very accurately the cost of the finished product, although unfortunately we cannot forecast the price that will be received. When on full feed a lamb will require about 3 pounds of hay and 1 pound of grain a day and on this feed should make a gain of ⅓ pound a day. This means that 300 pounds of grain and 900 pounds of hay will be required to produce 100 pounds of gain. Where the lambs are not on full feed, or where the feed is not strictly choice the gains will be slightly less than this. An average of all the grain and alfalfa tests on record shows a daily gain of .31 pound and a feed consumption of 2.8 pounds of alfalfa and .93 pound of grain. The feed per 100 pounds of gain would be the same in this case as quoted above; that is, 300 pounds of grain and 900 pounds of hay. On this basis where a 55-pound feeder lamb costs 10c a pound, alfalfa $10.00 a ton and barley $30.00 a ton, the cost of the finished lamb may be figured as follows:

Cost of 55 pound feeder lamb at $10 per 100 pounds	$ 5.50
Interest on above at 8% for 75 days	.09
Insurance at 1.6%	.09
225 pounds of alfalfa (3 pounds a day for 75 days) at $10 a ton	1.13
75 pounds of barley (1 pound a day for 75 days) at $30 a ton	1.13
Labor at $5 a day for 1000 lambs	.38
Lumber, dip and incidentals	.05
Final cost per head	$ 8.37
Gain per head	25 pounds
Final weight per head	80 pounds
Final cost per 100 pounds	$10.46

This means that a lamb costing $10.00 a hundredweight must, at the feed prices quoted, sell for $10.46 a hundredweight after 75 days feed, in order to pay for feed, interest, insurance, and labor. These are farm prices; if the lambs are bought or sold at more distant points, allowance for shipping costs must be made. In order that we may see at a glance the approximate cost of a finished lamb under a range of prices for feeder lambs, hay, and grain, the accompanying cost chart has been prepared (Table IV).

TABLE IV. FATTENING LAMBS ON HAY AND GRAIN.

	Price per 100 pounds at which the finished lamb must be sold in order to pay for feed, interest, and labor.			
	If feeder lambs cost 5c a lb.	If feeder lambs cost 7½c a lb.	If feeder lambs cost 10c a lb.	If feeder lambs cost 12½c a lb.
With alfalfa @ $ 5.00 and grain @ $15.00	$5.49	$ 7.28	$ 9.05	$10.81
With alfalfa @ $ 7.50 and grain @ $22.50	6.19	7.98	9.74	11.51
With alfalfa @ $10.00 and grain @ $30.00	6.91	8.70	10.46	12.24
With alfalfa @ $12.50 and grain @ $37.50	7.61	9.40	11.16	12.94
With alfalfa @ $15.00 and grain @ $45.00	8.31	10.10	11.86	13.63

It is apparent that under all ordinary price conditions the finished lamb in order to pay out must sell for more per hundred pounds than his original cost as a feeder. This difference between the price per hundred pounds of feeder lambs and the price per hundred pounds of fat lambs we call "margin." Fat lambs ordinarily sell for more than feeder lambs, partly because of their higher dressing percentage and better quality of mutton, and partly, in case of winter fed lambs, on account of the better market later in the winter. A fat lamb is ordinarily worth from 50c to $1.50 more per hundred pounds than a feeder lamb on the same market. When we add to this the improvement in the market later in the winter we usually expect a total margin of from $1 to $3 per hundred pounds. This is about what the lamb feeder gets as an average over a long series of years. On any particular year, however, he may get as high as $5 or $6 margin, or he may sell his lambs for $3 or $4 a hundred less than they cost. Lamb feeding for one or two years may rightly be considered as highly speculative, but when conducted through a long series of years, by men who are financially in a position to stand the losses of the bad years and counterbalance them with the good years, the speculative element very largely disappears and lamb feeding becomes about as stable a business as any other line of agriculture, and especially so since lambs are very dependable in the feed lot. Thrifty lambs given reasonably good feed and care practically never fail to make satisfactory gains and to take on a good finish.

Many feeders measure their financial returns in the terms of the price received for the feed used. Table V therefore gives the probable returns for the feed under various conditions:

TABLE V. NET PRICE RECEIVED FOR THE FEED NEEDED FOR FATTENING ONE LAMB: (225 POUNDS OF HAY AND 75 POUNDS OF GRAIN)

	Net price received for the feed
If lambs cost 5c and sell for 6c	$1.53
If lambs cost 5c and sell for 7c	2.33
If lambs cost 7½c and sell for 8½c	2.10
If lambs cost 7½c and sell for 9½c	2.90
If lambs cost 10c and sell for 11c	2.69
If lambs cost 10c and sell for 12c	3.49

Translated into tons and figuring one ton of grain the same as three tons of hay the prices received for the feed per ton would be as follows:

	Price received for feed per ton hay	grain
If lambs cost 5c and sell for 6c	$ 6.84	$20.52
If lambs cost 5c and sell for 7c	10.40	31.20
If lambs cost 7½c and sell for 8½c	9.33	27.99
If lambs cost 7½c and sell for 9½c	12.89	38.67
If lambs cost 10c and sell for 11c	12.00	36.00
If lambs cost 10c and sell for 12c	15.56	46.68

No credit has been allowed in these estimates for the refused hay. As previously noted, about twenty percent of the hay will be refused but this refused hay has a value of fifty percent that of fresh hay for stock cattle and horses. If this twenty percent of refused hay were utilized in such a way as to recover half of its original value it would represent a saving of ten percent in the total hay bill and the feeder would therefore do that much better financially than the figures we have quoted. In the estimates no credit has been allowed for the manure produced, although it may in many cases have a very considerable value. It may be safely figured that for each ton of hay or grain fed to fattening lambs there will be produced 1¾ tons of manure. From this the farmer may make his own estimate to the credit he can allow for this item.

WHO SHOULD FEED LAMBS

The fattening of lambs should be considered as a means of marketing surplus alfalfa hay and grain, for which there is no other satisfactory outlet. The fattening of lambs, one year with another, has afforded a very satisfactory market, but owing to the extreme fluctuations in prices it has been dangerous and often disastrous. No one should attempt the business of fattening lambs unless his financial position is strong enough to permit him to stand a heavy loss and still continue. In the long run the good years will offset the bad, but if a man is not in a fairly strong financial position and the bad year comes first he will not be in a position to continue.

No one should attempt to fatten lambs without a thorough understanding of the amounts of feed required and the probable gains that will be produced. The feeder necessarily should have a liking for the business and the intention to stay with it. It is not, however, necessary for him to have long or extensive experience in the handling of sheep. Any feeder who will follow carefully the instructions in this circular will have no trouble in making good gains and in producing fat lambs.

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Oregon Agricultural College

Experiment Station

Sulfur in Relation to Soil Fertility

By

W. L. Powers

CORVALLIS, OREGON

The regular bulletins of the Station are sent free to the residents of Oregon who request them.

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SUMMARY

The experiments herein reported, covering the progress of sulfur investigations with Oregon soils, are maintained by the Soils department of the Oregon Agricultural College Experiment Station as a phase of Oregon Soil and Soil Water Investigations provided for in Ch. 340, Session Laws of 1919 and its continuations. Earlier studies along this line were reported in Oregon Station Bulletins 163 and 167, now out of print. The present bulletin is prepared to meet the heavy demand for information on the subject of sulfur in relation to soil fertility. Most of the quantitative analyses were made by the department of Agricultural Chemistry and bacterial studies were made by the department of Bacteriology.

1. In 1912 the Oregon Experiment Station found that increases in alfalfa yields equivalent to those obtained by use of potassium sulfate in Eastern Oregon experiments by W. L. Powers and by use of acid phosphate in Southern Oregon experiments by F. C. Reimer could be obtained by use of elemental sulfur.

2. Subsequent analyses of soils and crops indicated, and field, greenhouse, and laboratory experiments seem to confirm the view that sulfur is a limiting element, and that the increase caused by its application was not to any great extent due to indirect action.

3. Similar tests of the leading two dozen arid and semi-arid soil types of Oregon proved that there are at least 100,000 acres of alfalfa that can be increased one ton or more an acre each year with sulfur at a cost not exceeding one dollar a ton for the sulfur applied.

4. Legumes, particularly alfalfa, red and alsike clover, have given marked response to sulfur fertilizers. Moderate increases have been obtained on wheat and potatoes, and but little increase from this treatment where field peas, beans, corn, kale, rape, or sunflowers were grown. The benefit with potatoes is attributed largely to indirect action in controlling potato scab and some increase in ammonification.

5. H. V. Tartar and H. G. Miller of the Oregon Experiment Station found that sulfur increases protein content of crops.

6. Numerous recent analyses and four fertility field experiments show that the extensive red hill regions extending from Coos Bay to Astoria and from the Pacific to the Cascades, covering the Coast hills and the hills surrounding the Willamette Valley, contain only 150 to 400 pounds of sulfur in the plowed surface of an acre, and yield 25 to 50 percent increase of clover when sulfured. The same is true regarding grain from sulfur applications.

7. Sixty years of cropping has depleted this initial supply in representative soil types from 300 pounds to 200 pounds an acre, and the indication is that available sulfur is deficient at the close of the rainy season.

8. Lysimeter studies show that 40 to 45 pounds of sulfur is lost in the annual percolate, while only 3 to 6 pounds an acre a year is received in the annual precipitation.

9. Laboratory experiments strongly indicate that a little gypsum or sulfur and lime aids nitrification at the beginning of the growing season, there being practically no nitrates in Western Oregon soils at that time because of low temperature and excessive moisture. After the cold, wet weather has depleted the nitrate and sulfate supply in Western Oregon, the sulfur or calcium sulfate (gypsum) aids in establishing a stand of new clover. Sulfur seems to be related to nitrogen supply.

10. Sulfofication* studies by Professor Halversen of the Bacteriology department show that most of the Oregon soil types contain organisms capable of oxidizing sulfur more rapidly than is necessary for plant needs. Sulfur applied to field plots has caused visible results in two weeks. Elemental sulfur is the most economical form. It should be applied early and harrowed in to insure results the first season.

11. Water culture, and pot culture and tank experiments strongly indicate that sulfur is an especially critical element, but that only a small amount is necessary. Yields have been markedly increased and water requirements strikingly decreased by adding a little sulfur against its elimination or near elimination.

12. From a study of the literature and inquiry of experiment stations throughout the United States, it seems that the basaltic region of the Northwest is the greatest field for the profitable use of sulfur. Basalt contains only limited amounts of sulfur. Soils receiving large quantities of sulfate bearing irrigation water, those high in organic matter, and those containing sulfate alkalies in the Great Basin region are plentifully supplied with sulfur; while soils in eastern and southern states receive a fair supply of sulfur in fertilizers, manures, and from precipitation in the heavy coal-consuming sections.

13. Thorough field experiments with sulfur as a fertilizer in Oregon, now of ten years' duration, are believed to be the most extensive to be found. Applications amounting to 1,000 pounds of sulfur an acre during this period have resulted in continued marked increase in yield. The duration of the increase in yields from a hundred-pound application on an acre of soil is three to five years, the heavier soil types retaining sulfur longer. Maintenance of one element will not make a permanent system of agriculture.

14. Use of elemental sulfur beyond the amount needed to meet the absolute deficiency has tended to aggravate soil acidity in humid and semi-humid sections, as judged by Truog acidity tests of Southern and Western Oregon soils made by the Soils department and hydrogen-ion tests made of samples submitted to the department of Bacteriology.

15. It appears that sulfur may be used on red hill soil at one-third the cost of sulfur secured in gypsum, the use of which is common in Western Oregon. Its continued use will make occasional liming more necessary. A combination of sulfur, rock phosphate, manure, and lime has given maximum yields in some recent field experiments.

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* Sulfur oxidation.

Sulfur in Relation to Soil Fertility

By

W. L. Powers

INTRODUCTION

Until recent years investigators have generally agreed that the chemical elements in which soils are most often deficient are potassium, nitrogen, and phosphorus. To supply these elements a great fertilizer industry has been built up. In addition calcium is often needed in carbonate form to correct soil acidity. The older systematic fertilizer experiments have been worked out on this basis.

Although sulfur has long been regarded as essential to plant growth, the small amount formerly found in plant ash did not indicate that it was likely to be a critical or limiting element in crop production. During recent years, however, an improved fusion method of analysis has shown that such plants as alfalfa and the cabbage family show much more sulfur than early analyses indicated. A five-ton crop of alfalfa removes about twenty-five pounds of sulfur from one acre, whereas only twenty-five pounds or less of phosphorus would be contained in five tons of alfalfa. On the new basis rape has been found to contain twenty pounds of sulfur in a ton; and a fifty-bushel oat crop, including straw, would remove about sixteen pounds of sulfur.

The use of sulfur as a fertilizer began as early as 1913 in Oregon, and systematic field and laboratory experiments which have extended over a period of years give perhaps the most marked increases in yields that have been secured by investigators of sulfur in relation to soil. Since previous reports of sulfur experiments in Oregon are out of print and many new facts have been developed, a statement of the progress of these studies is here given to meet the large demand for information on this subject.

This bulletin is issued as a feature of Oregon Soil and Soil Water Investigations as provided for by the state legislature, Chapter 340, Session Laws 1919 and its continuations, 1921 and 1923.

Acknowledgement. The author here wishes to acknowledge the careful assistance of field agents W. W. Johnston, John Tuck, K. S. Taylor; laboratory determinations by Professor J. S. Jones and associates in the Experiment Station chemical laboratory; and suggestions and tests by Professor W. V. Halversen of the Bacteriology department. Helpful suggestions have been received from Director J. T. Jardine, Professors C. V. Ruzek and F. C. Reimer. Professor Reimer furnished data for experiments in Southern Oregon prior to 1918. The cooperation of branch experiment station superintendents and county agents has made possible a more extensive and correlated study than otherwise would have been possible.

Historical: Investigations in other states. A thorough review of literature dealing with sulfur as a plant food[1] has recently been issued, and space here permits mention of only essential facts developed. The value of sulfur was recognized in France and Germany during the last half of the eighteenth century. Calcium sulfate was probably first used in America by Benjamin Franklin on his farm near Philadelphia. Hart and Peterson of the Wisconsin Experiment Station, using new methods of analysis found[2] the sulfur removed by average crop cereals to be about two-thirds of the phosphorus removed by these crops, while alfalfa required more sulfur than phosphorus. One hundred average crops of barley would require as much sulfur as is contained in the surface eight-inches of an average soil. Crops such as cabbage and turnips removed two or three times as much sulfur as phosphorus. It was also found that this soil farmed fifty to sixty years lost on the average 40 percent of the original sulfur content as compared with virgin soil. They calculated that the amount of sulfur lost in drainage water would exceed the amount brought in by the atmosphere and rain.

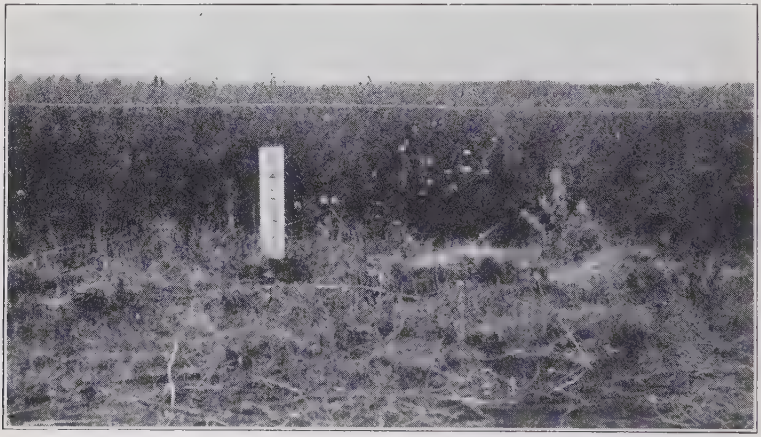

Fig. 1. Original sulfate plots, Redmond, 1912, untreated.

These facts led to renewed interest in sulfur content of soils. A thorough study of the sulfur content of Kentucky soil areas, made by Shedd,[3] shows that soils of that state usually contain less sulfur than phosphorus and that many staple crops respond to treatment with sulfur and sulfate. For years people have often applied sulfur to soil unknowingly in manure, potassium sulfate, ammonium sulfate, acid phosphate, and calcium sulfate.

It has been found that amounts of sulfur ranging from three to fifty pounds per acre each year, are added by rainfall, while the amount in drainage water has frequently been much larger.

A study of twenty years' fertilizer trials of the Ohio Experiment Station[4] shows the average yield of plants treated with acid phosphate, potassium sulfate, or ammonium sulfate to be higher than those treated with fertilizers containing no sulfur. In Illinois experiments potassium sulfate has not materially increased yields on normal soils.[5] Thirty-five years' use of gypsum at the Pennsylvania Experiment Station and eighteen years' use at the Ohio Experiment Station have not materially increased average yields. Various effects of sulfur have been noted.

Sulfur is used by the plant in the sulfate state, and Dr. P. E. Brown of the Iowa Experiment Station has shown that different groups of bacteria are associated with the oxidation of sulfur into available form.[6] Inoculation studies to hasten oxidation, or sulfofication, have been made at the New Jersey Experiment Station by Lipman.[7] At that station and others sulfur has been composted with raw rock phosphate to make available phosphate and with fair success. Increased activity of nitrifying bacteria due to sulfur and lime has been reported by different investigators. Greater root and nodule development has been noted and a higher protein content in crops secured. Some field and laboratory studies have been made with sulfur in the state of Washington,[1] and increases have been obtained in the yields of alfalfa from gypsum applications. Results have been less striking than those obtained in Oregon. Increases in yields have also been noted from studies in Utah, Montana, Idaho, and California. In the last named state the effects of sulfur, sulfuric acid, and sulfate have been considered in connection with the correction of alkali.[8]

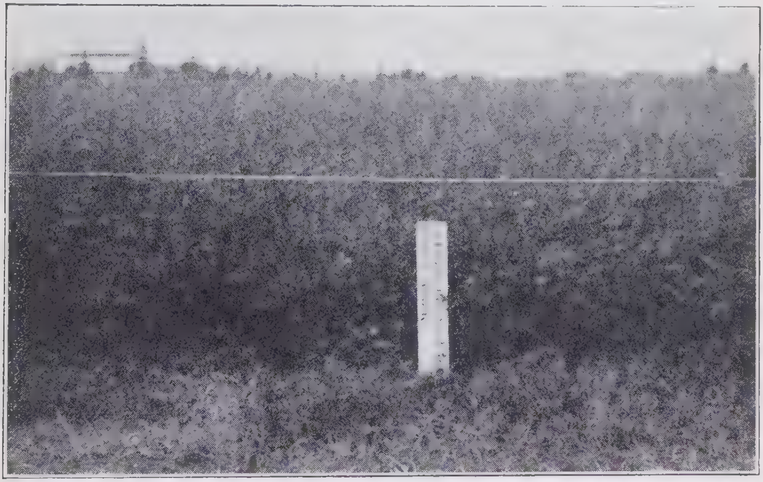

Fig. 2. With sulfur. Redmond, 1912.

Sulfur has been regarded as a stimulant by some,[9] and heavy applications have been made in France for that purpose. Use of sulfur has resulted in increased solubility of phosphorus and potassium compounds in soils. Sulfur was noted by McCool to hasten decay of organic matter.[10] The tendency of heavy applications to increase acidity has been variously reported. Indirect effects attributed to sulfur by various investigators include control of potato scab fungus[11] through increase in hydrogen-ion concentration and repelling of wireworms and other insects.

Experiments in Oregon. Superphosphate, gypsum, and other fertilizers gave indications of the importance of sulfur in Southern Oregon experiments made by F. C. Reimer 1912.[12] Potassium sulfate, superphosphate, and gypsum gave increases in Central Oregon fertilizer experiments by the writer that same season,[13] indicating the great value of sulfur in that section. These experiments led to the first trials in Oregon with elemental sulfur on soils in the Willamette and Deschutes valleys under irrigated conditions the following year, 1913. It was proved that increases secured by other sulfates could be obtained by use of elemental sulfur.

The importance of sulfur in connection with the results secured in these early experiments was perhaps first suggested by H. V. Tartar, at that time Chemist at the Oregon Experiment Station. In 1913 Professor Tartar published an article giving the new figures for the sulfur content of staple crops and calling attention to the unconscious use of sulfur in acid phosphate, gypsum, and other fertilizers,[14] thus questioning the sufficiency of sulfur. A brief announcement was made in 1914 by Professor Reimer[15] pointing out that lime-sulfur spray benefited legume cover crops beneath sprayed trees and indicated benefits from sulfur in this spray as well as in superphosphate, which also helped.

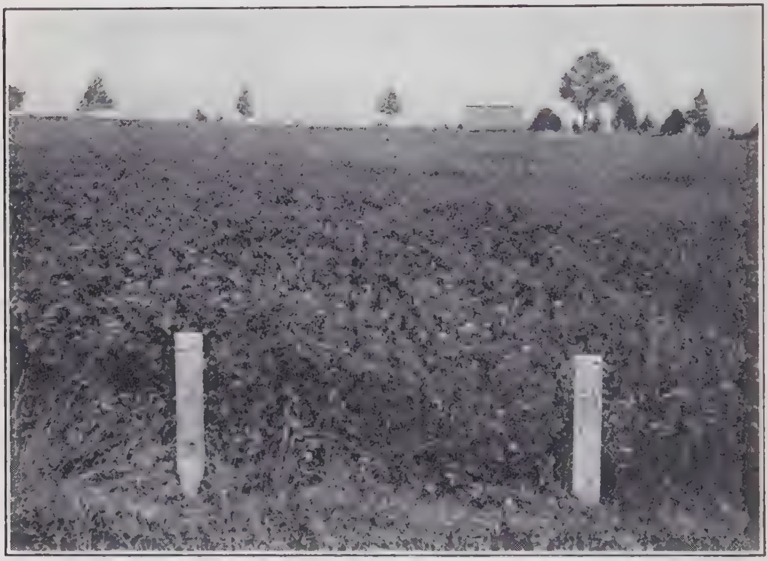

Fig. 3. Sulfate on clover. Redmond, 1912.

Professor Reimer used elemental sulfur in 1914 and obtained as good increases as with gypsum or superphosphate. Little or no increase was realized from rock phosphate. These Southern Oregon experiments were extended to fairly comprehensive fertilizer experiments during the following years. Fertilizers containing sulfur gave striking increases, whether flowers of sulfur, superphosphate, gypsum, iron sulfate, sulfate of ammonia, sulfate of potash, sulfate of magnesium, or sodium sulfate. In these trials nitrate of soda, monocalcium phosphate, chloride of potash, and ground limestone have had little effect upon alfalfa, showing that the increase is not due to liberation of phosphorus or potash or lack of lime in the soil. Chemical analyses proved that these soils were well supplied with potassium, lime, magnesium, and iron, were slightly alkaline, and were often low in sulfur.

Miller studied the effect of sulfur and sulfate in pot cultures[16] and found increased growth of plants in the greenhouse, indicating that sulfur was a direct aid in plant growth. He attributed the great increase in the nitrogen content of clover where sulfates were added to the increased action of legume bacteria, the sulfate causing greater development of nodules.

Sulfur studies have been conducted in the Deschutes Valley in Central Oregon with some minor interruptions since 1913, and in Southern Oregon and the Willamette Valley continuously since 1914. Field trials have been extended to most of the alfalfa-producing sections.

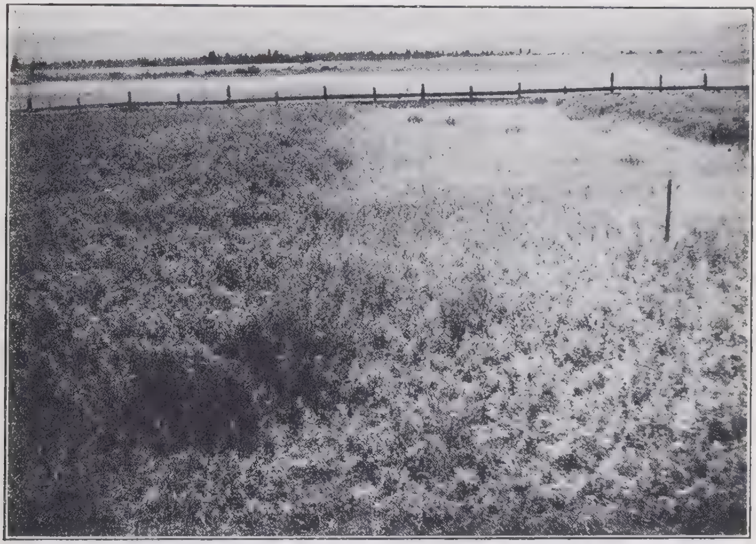

Fig. 4. Sulfur fertilizers plots in Southern Oregon.

The studies in Eastern Oregon were extended to Goose Lake Valley in 1915, and sulfur has doubled the yield on several fields there where results have been noted during the past eight years. Six years' results from field trials are available in Klamath county, and a single application of one hundred pounds on an acre has made in the six years an increase in yield of nearly two tons a year or a total of eleven for the period. There will be a 50 percent increase there from sulfur this, the seventh, year. The average increase from all sulfur trials in Deschutes Valley has been 1.8 tons an acre. During the past five years, sulfur trials have been carried on by the Experiment Station, and sulfur has been included in systematic (or complete) fertilizer experiments on many leading soil types of the state. Those have proved that at least 100,000 acres of alfalfa land in Oregon can be increased by one ton an acre in hay yields or a possible increase in hay value of $1,000,000 a year.

Cooperative extension demonstrations. Cooperative demonstrations have been carried on during the past several years with the county agents in Oregon. In Klamath county, in careful checks made on twenty-seven fields which have been treated with sulfur, the average increase was 145 percent. On many of the soils, the increase was close to two tons an acre. Demonstration experiments comparing gypsum and sulfur were conducted in Grand Ronde Valley. Early results there favored gypsum, but sulfur is proving more economical in the long run. County agents report six cars of sulfur and eight cars of gypsum secured cooperatively during one season and applied to several thousand acres to provide sulfur for alfalfa lands. Including areas previously treated this brings the total area treated to sulfur in Oregon to about 25,000 acres. The average increase in hay on this will be at least a ton an acre, worth at $10 a ton, $250,000.

PLAN AND PURPOSE OF EXPERIMENTAL WORK WITH SULFUR

The writer started with sulfur investigations in Eastern Oregon in 1912 and 1913 and has been interested in the extending of these trials to different sections of the state. After the Soils department was organized in its present form sulfur studies centering around the field experiments were organized into a definite project for determining more accurately the functions and value of sulfur in relation to soil fertility. The trials were extended with the following objectives:

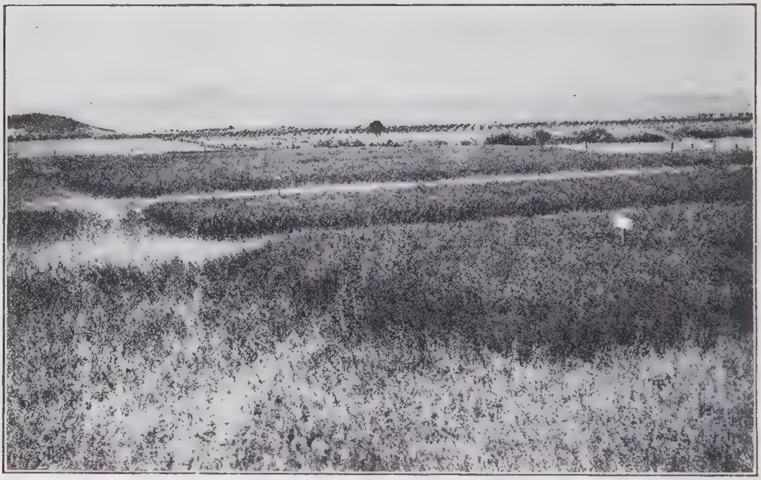

Fig. 5. Sulfur vs. no fertilizer, Southern Oregon.

1. To determine the value and ultimate effect of the long-continued use of sulfur fertilizer on soil reaction and fertility. Also the value of important elements with and without sulfur.

2. To study the losses and gains of sulfur in soils from rainfall and drainage.

3. To determine the value of sulfur when applied to various crops and different soil types.

4. To determine the value of sulfur, gypsum, and aluminum sulfate used in connection with sweet clover in restoring the structure of drained alkali lands.

5. To determine the value of sulfur, manure, ground limestone, and ground rock phosphate combinations for making available the phosphorus needed by crops.

6. To determine the value of sulfur and sulfate applied alternately with ground limestone in humid sections.

When systematic field fertilizer trials were extended in 1918 to many additional soil types, plans were arranged to include trials of sulfur in each of these field fertilizer experiments. A lease had been arranged for protecting the sulfur experiments started by Reimer in Southern Oregon, and these experiments were extended and brought under irrigation. There are now sulfur experiments in Western Oregon that have been under continuous observation for nine years and in Southern Oregon eight years.

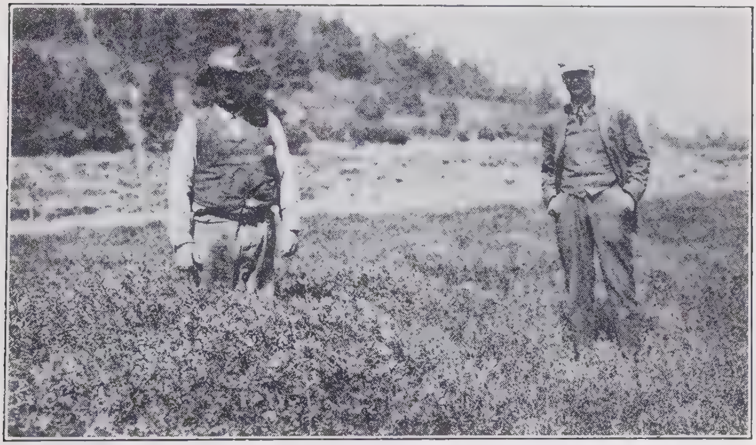

Fig. 6. Effect of sulfur in Klamath Basin.

Sulfur content of soils. In connection with the detailed soil surveys official soil samples collected have been submitted to the department of Agricultural Chemistry; and since these chemical studies have included sulfur content, nearly all soil types in Willamette Valley and Southern Oregon have thus been tested for their sulfur content. Samples taken in the Willamette Valley have been from virgin soils, and this has been true of a number of samples secured and tested in connection with feasibility surveys on reclamation projects in Eastern Oregon.

These samples are usually taken to a depth of about 7 inches in the humid sections or to 12 inches depth for the surface samples in arid sections. The surface samples tested from Jackson county were taken from cropped fields to a depth of 15 inches. Available data as to sulfur content of Oregon soils employed in sulfur tests have been summarized

TABLE I. SULFUR CONTENT OF SOILS

Determinations by Department of Agricultural Chemistry

Area	Soil type	County	Depth in inches	Sulfur in 2,000,000 pounds surface soil	Phosphorus in 2,000,000 pounds surface soil
				lbs.	*lbs.*
Willamette Valley					
Hill	Melbourne clay loam	Washington	0–16	162	1400
	Carlton silt loam	Washington	0–16	124	1260
*	Carlton silty clay loam	Benton	0– 8	300	-------
*	Olympic silt loam	Marion	0– 8	580	-------
	Aiken silt loam	Washington	0–12	70	640
	Aiken silt loam	Yamhill	0–20	340	3400
	Aiken silty clay loam	Yamhill	0–10	540	4200
Old Valley	Powell silt loam	Multnomah	0–12	320	2540
	Willamette silt loam	Washington	0–18	260	3440
	Willamette silt loam	Yamhill	0–12	390	2240
	Hillsboro silt loam	Washington	0–30	260	1320
	Amity silt loam	Washington	0–18	360	2780
	Salem loam	Multnomah	0–12	640	2700
	Grande Ronde silty clay loam	Yamhill	0–20	700	2440
Recent sedimentary	Chehalis fine sandy loam	Yamhill	0–20	162	980
	Chehalis silty clay loam	Washington	0–14	140	1240
	Whiteson silt loam	Yamhill	0–12	320	1000
	Wapato silt loam	Washington	0–14	380	600
	Newberg clay loam	Multnomah	0–12	680	1580
	Wapato silt loam	Yamhill	0–12	460	1620
	Whiteson silt loam	Washington	0–18	1100	920
	Sauvie sandy loam	Multnomah	0–12	940	2440
Peat	Peat	Yamhill	0–12	3920	1880
	Peat	Washington	0–12	5000	2060
Southern Oregon					
	Corning clay loam	Josephine	0–12	140	960
	Aiken clay loam	Josephine	0–12	154	920
	Kirby loam	Josephine	0–12	180	1920
	Clawson clay loam	Josephine	0–12	220	240
	Columbia gravelly clay loam	Josephine	0–12	600	3840
	Salem fine sandy loam (coarse)	Jackson	0–15	300	1520
	Salem gravelly sandy loam	Jackson	0–15	380	1720
	Siskiyou coarse sandy loam	Jackson	0–15	380	2018
	Antelope clay adobe	Jackson	0–15	400	1280
	Phoenix clay adobe	Jackson	0–15	420	960
	Agate gravelly loam	Jackson	0–15	480	1140
	Agate gravelly sandy loam	Jackson	0–15	480	1640
	Salem clay loam	Jackson	0–15	540	1000
	Salem clay adobe	Jackson	0–15	540	1640
	Barron coarse sand	Jackson	0–15	560	1540
	Coker clay adobe	Jackson	0–15	560	1360
	Meyer silty clay loam	Jackson	0–15	580	1200
	Tolo loam	Jackson	0–15	580	1300
	Olympic clay adobe	Jackson	0–15	600	1380
	Climax clay adobe	Jackson	0–15	600	1000
	Sites fine sandy loam	Jackson	0–15	620	1580
	Medford fine sandy loam	Jackson	0–15	640	1040

	Salem fine sandy loam	Jackson	0–15	680	1920
	Medford loam	Jackson	0–15	720	1300
	Coleman gravelly loam	Jackson	0–15	740	1300
	Meyer clay adobe	Jackson	0–15	760	1180
	Medford gravelly clay loam	Jackson	0–15	760	1380
	Bellavista fine sandy loam	Jackson	0–15	800	1840
	Sites sandy loam	Jackson	0–15	819	900
	Neal silty clay loam	Jackson	0–15	900	1560
	Neal clay adobe	Jackson	0–15	900	1940
	Sam's loam	Jackson	0–15	980	1920
Greater John Day Project—Central Oregon					
	Fine sandy loam	Shutler flat	0–12	320	4200
	Fine sandy	Bench west of Butter Creek	0–12	240	4600
Lower Powder					
	Gravelly silt loams	....	....	150	1528
	Light silt loam	....	....	1440	934
	Gravelly loam	....	....	500	3230
Deschutes					
	Medium loamy sand	Redmond	....	646	2009
	Medium loamy sand	Powell Butte	....	160	....
	Cropped vs. Virgin Soils				
Willamette Valley					
Abraham farm	Cultivated 50 years	Corvallis	....	280	....
Abraham farm	From fence line	Corvallis	....	300	....
Howd farm	Cultivated 50 years	Waldo hills	....	460	....
Howd farm	From fence line	Waldo hills	....	580	....
Central Oregon					
Bassett farm	Cultivated 14 years	Powell Butte	....	140	....
Bassett farm	From fence line	Powell Butte	....	160	....

Other regions	Authority	Range	Range
Earths Crust	Clarke	2200	1921
United States	Robinson	160–2600	U. S. Dept. of Ag. Bul. 122
Illinois	Illinois Exp. Sta.	600–1000	1000–2000
Iowa	Brown and Kellogg	719– 938	
Ohio	Ames and Boltz	412– 800	
Indiana	Conner	480	
Eastern Washington	Olson and St. John	246– 712	
Wisconsin	Hart and Peterson	400–1200	
Kentucky	Shedd	360–1000	540–5550

in Table I. Samples of fields that have been cropped for a generation have been collected and analyzed, as have also adjacent virgin soils of undisturbed boundary or fence lines from sections where sulfur appears to be an important factor in connection with soil fertility.

The sulfur content of Southern Oregon soils runs from a hundred and forty pounds to eight hundred pounds in the plowed surface of an acre (six and two-thirds inches depth), or approximately 2,000,000 pounds. Many of the surface soils there contain less than 500 pounds of sulfur.

In the Willamette Valley the soils in the Valley floor contain a moderate amount of sulfur, usually 300 to 600 pounds in 2,000,000 pounds soil. The soils in the recently formed stream bottoms, with certain exceptions, contain 200 to 1,000 pounds of sulfur. According to analyses made, the soils in the hill lands in the Willamette Valley region are often low in sulfur, running frequently from 100 to 300 pounds in 2,000,000 pounds soil.

Few determinations have been made of Eastern Oregon soils. They frequently contain less than 500 pounds in the furrow stratum. The leading irrigated crop there is alfalfa, which for an average yield requires about twenty-five pounds of sulfur a season. Some Oregon soils contain ten times as much phosphorus as sulfur; while the leading crops, particularly in the arid and semi-arid sections, often require more sulfur than phosphorus and the crops grown require much less phosphorus than the corn crop in the central states.

Basaltic soils rather low in sulfur. Soil analyses from other states and replies to inquiries from experiment stations throughout the United States indicate that the basaltic soils in the Pacific Northwest offer a very great field for increased crop yields from the use of sulfur to supplement the moderate supply frequently found present in these soils. Basaltic rocks contain relatively small amounts of sulfur.[17] In the Great Basin sulfates are associated with the alkali, which is more common there. In the southern and eastern states the liberal use of sulfate-bearing fertilizers has probably overcome any deficiencies in sulfur that might have existed. There appears to be less sulfur than phosphorus in soils generally; different investigators have found losses of 20 to 40 percent in soils cropped for a generation as compared to virgin soil. Indiana[18] and Kansas[19] stations report moderate amounts of sulfur in soils of those states and find it readily available so that crop needs are considered satisfied. Stewart[5] considered sulfur from rainfall sufficient in Illinois to meet crop needs. Cropped Oregon soils show consistently lower amounts of sulfur present as shown in Table I from determinations by Oregon Experiment Station chemists.

Sulfur content of crops. Hart and Peterson[2] in 1911 reported new figures for sulfur content of crops. Reimer and Tartar[12] found that alfalfa from sulfur-treated plots contained a higher percentage of sulfur than alfalfa from untreated plots, and that it also contained sulfates. Similar increases in sulfur content of other crops due to use of sulfate-bearing fertilizers have been reported by Iowa, Wisconsin, and Kentucky experiment stations.[1] These increases appear to be associated with a higher protein content in sulfur-fertilized crops. Different investigators have shown that crops belonging to the legume and cabbage families contain more sulfur than phosphorus. The sulfur content of crops is shown in Table II. It will be seen that legumes especially require nearly as much sulfur as phosphorus, while the supply of sulfur in soils is much lower.

TABLE II. SULFUR CONTENT OF CROPS

Determinations by Department of Agricultural Chemistry
(Oregon Station Bulletin 197)

Crop	Number of determinations	Pounds in 1000			
		Air dry		Oven dry	
		Sulfur	Phosphorus	Sulfur	Phosphorus
Alfalfa	21	1.90	2.10	2.04	2.26
Red clover	23	1.00	1.70	1.08	1.42
Alsike clover	10	1.45	1.86	1.20	2.03
Sweet clover	3	1.49	2.03	1.59	2.17
Vetch	22	.87	2.31	.95	2.53
Peas	5	1.08	2.07	1.16	2.23
Timothy	3	.70	1.65	.75	1.77
Orchard grass	....	.44	1.41	.48	1.53
Bunch grass	....	.86	1.26	.92	1.35
Sunflowers	....	1.55	4.37	1.62	4.59
Wheat	3	1.13	3.53	1.28	3.54
Oats	5	1.27	3.52	1.40	3.88
Barley	6	1.00	3.74	1.13	4.21
Corn	2	1.09	3.14	1.21	3.50
*Potatoes	....	......	......	1.17	2.79
Onions	....	......	......	5.68	2.50
*Cabbage—Wisconsin	....	......	......	8.16	5.50
*Rape—Ohio	....	......	......	10.49	1.09
*White Beans	....	......	......	2.32	9.60
Soy-beans—Wisconsin	....	......	......	2.81	......

*Data from other experiment station publications.

Sulfur in rainfall and irrigation and drainage water. Coal smoke carries appreciable quantities of sulfur and probably influences the amount brought down to the land in rainfall where there is thick settlement or where industrial activities abound. Volcanic activity may at times influence accretion of sulfur by soil from the atmosphere.

Irrigation water may contribute sulfur to the soil. Water pumped for irrigation from a semi-artesian well and rising from a flow 218 feet below the surface at the Harney Branch Experiment Station, Oregon, was submitted to analysis. The Station Chemist's test shows that this water carries 2.01 pounds an acre foot of sulfur in sulfate form. Irrigation water used on Umatilla Branch Experiment Station is reported by Superintendent Dean to carry 2.29 pounds sulfur an acre foot. Coarse sand soil at that Station requires about five acre feet an acre of irrigation a season and this water appears to carry sufficient quantities of sulfur to supplement the soil supply for crops. Streams used for irrigation in the Great Basin and in the southwestern states carry appreciable amounts of sulfur in solution plus some in suspension.

Sulfur in rainfall. Precipitation for the past two rainy seasons at the Oregon Experiment Station, Corvallis, has been carefully collected and submitted to the Station Chemist for analysis for total sulfur. The pounds of sulfur an acre received in precipitation and amounts carried out in drainage from lysimeter tanks containing four feet of soil are shown in Table III, A, B, C.

TABLE III-A. SULFUR IN RAINFALL AND IN DRAINAGE FROM LYSIMETERS, 1920-21

(Determinations by department of Agricultural Chemistry, Oregon Experiment Station, from samples submitted by the Soils department.)

	Rainwater		Lysimeter No. 4 Willamette silty clay loam		Lysimeter No. 8 Dayton silty clay loam	
	Rain	Sulfur per acre	Percolated	Sulfur	Percolated	Sulfur per acre
	in.	*lbs.*	*in.*	*lbs.*	*in.*	*lbs.*
Winter 1920-21						
November	4.90	.350	2.31	--------	2.33	--------
December	7.97	.654	6.39	1.827	7.49	4.641
January	7.15	.118	7.19	3.499	6.84	3.586
February	5.38	.351	5.82	3.595	4.99	2.397
March	4.23	Lost	3.10	1.936	3.13	1.825
April	1.99	------	.07	T	.01	T
	31.62	------	------	------	------	--------

TABLE III-B. WILLAMETTE SILTY CLAY LOAM, 1921-22

	Rain		Lysimeters Nos. 1 and 4 Manured		Lysimeters Nos. 2 and 3 Untreated	
	in.		*in.*	*lbs.*	*in.*	*lbs.*
Winter 1921-22						
November	5.36	Partial	8.02	11.83	9.40	10.66
December	3.48	data	3.64	4.49	3.62	5.04
January	3.80	only	3.75	3.28	4.39	7.33
February	4.85	------	4.33	2.91	5.54	10.02
March	5.81	------	3.65	2.10	4.76	8.26
April	1.77	------	.68	.50	1.15	2.42
				25.11		43.73

TABLE III-C. SULFUR IN DRAINAGE WATER FROM LYSIMETER, 1922-1923

		Willamette silty clay loam							
		Lysimeter 1. Untreated		2. Manured, limed 20 tons to acre 3 tons to acre		3. Manured 20 tons to acre		4. Limed 3 tons to acre	
	Rain	Percolate	Sulfur	Percolate	Sulfur	Percolate	Sulfur	Percolate	Sulfur
	in.	*in.*	*lbs.*	*in.*	*lbs.*	*in.*	*lbs.*	*in.*	*lbs.*
1922									
Nov.	3.07	--------	--------	2.75	3.85	2.59	3.35	2.55	2.16
Dec.	11.11	3.09	2.750	8.79	11.90	11.15	24.05	11.01	7.83
1923									
Jan.	10.88	6.68	3.890	8.43	19.15	10.05	23.52	10.08	10.24
Feb.	2.16	2.04	.74	2.54	4.79	3.19	5.29	2.52	1.34
Mar.	2.57	.86	.37	1.55	2.64	1.65	2.35	1.48	.91
Totals	29.79	12.67	7.75	24.06	42.33	28.63	58.56	27.64	22.48

The data indicate that only a few pounds of sulfur may be expected from precipitation, while drainage loss may run twenty to forty-five pounds or more an acre, indicating an important net loss. In Western Oregon, section B of the percolation data shows a much higher loss from heavy soils that have been manured. Section C shows that lime is effective in liberating sulfur.

Stewart reports 45.1 pounds an acre a year received in precipitation at the Illinois station as a seven-year average.[5] MacIntire[20] found 49.6 pounds of sulfur an acre added by precipitation at Knoxville, Tennessee. Hart and Peterson[2] found the amount received annually to be 7 pounds in Wisconsin. The Ohio Experiment Station[4] cites Russian data showing 9 pounds in country and 72 pounds near towns received from rainfall and estimates that 6 to 7 pounds an acre a year is received in the United States.

Loss of sulfur in drainage has been estimated at 20 to 80 pounds an acre from data collected at Rothamsted, England. Lyon reports that in New York sulfur in drainage from fallow tanks about equalled that removed by crop and drainage in cropped tanks.

Wisconsin studies[2] place loss in drainage at three times that received by rainfall, while Tennessee studies[20] show annual loss from lysimeter tanks at 13 to 64 pounds an acre a year, depending upon treatment applied.

FIELD EXPERIMENTS

Important early field experiments. Experimental results leading to use of sulfur as a fertilizer in Oregon are out of print and are therefore reviewed here for convenience. See Table IV.

TABLE IV-A. VALUE OF FERTILIZERS AND THEIR RELATION TO ECONOMICAL USE OF IRRIGATION WATER

Deschutes Medium Sandy Loam, Redmond, 1912.

Crop	Irrigation, total depth	Fertilizers per acre	—Yield per— acre	water inch	——Gain in—— yield	value	Cost of fertilizer	Profit (or loss)
	in		*tons*	*tons*	*tons*			
Alfalfa	21	None	3.00	.143	------	------	------	------
Alfalfa	21	Potassium sulfate 160	3.96	.186	.96	$8.68	$4.00	$4.68
Alfalfa	21	Gypsum 60	3.40	.162	.41	3.69	.45	3.24
Alfalfa	21	Potassium chloride 160	3.27	.165	.27	2.43	4.00	−1.57
Old clover	24	None	3.33	.138	------	------	------	------
Old clover	24	Potassium sulfate 160	5.04	.210	1.71	15.39	4.00	11.39
Old clover	24	Gypsum 60	3.48	.145	.25	2.25	.45	1.80

TABLE IV-B. FERTILIZER USED AND ALFALFA YIELDS, MEDFORD FINE SANDY LOAM

Plots one-tenth acre in size. Fertilizer applied April 11, 1912

Plot	Application		Yield first cutting tons an acre
		lbs.	*tons*
1	Dried blood	50	1.85
2	Superphosphate	50	2.45
3	Muriate of potash	25	1.65
4	Dried blood	50	2.35
	Superphosphate	50	------
5	Dried blood	50	1.95
	Muriate of potash	25	------
6	Superphosphate	100	2.09
	Muriate of potash	25	------
7	Dried blood	25	2.26
	Superphosphate	50	-----
	Muriate of potash	25	------
8	Gypsum	40	2.07
9	Checks (Ave. 7 trials)	------	1.76

The experiment conducted on sandy loam in the Deschutes Valley in 1912 (Table IV-a) was planned to determine whether the local practice of using gypsum was not due to its effect in releasing potash for crops. The results of the experiment indicated very strongly that crop increases obtained were mainly due to sulfur contained in the applications. The following year elemental sulfur was used which about doubled the yields, showing that it was sulfur and not potash that caused the increased yield.

In the Rogue River Valley (Table IV-b), the superphosphate and gypsum applied to Medford fine sandy loam produced a denser stand of dark green color and increased yields, while other fertilizers did not cause difference in appearance from the check plots; the alfalfa possessing a pale green color. The increase obtained by superphosphate was at the time attributed to phosphorus, but trials the following year gave no increase from use of raw rock phosphate, and in 1914 yields of alfalfa were about doubled by the use of sulfur in elemental form and in superphosphate and iron sulfate as well. Rock phosphate had no effect, therefore it was the sulfur and not the phosphorus that caused the increased yield and rich color of alfalfa.

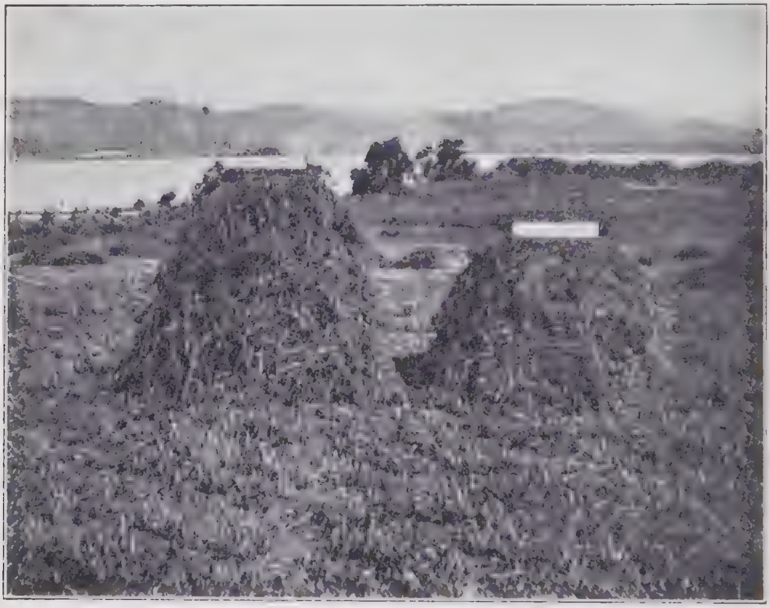

Fig. 7. Sulfur yield 8¾ tons treated, 5 tons untreated, Klamath.

PROGRESS OF SOUTHERN OREGON EXPERIMENTS

More permanent experiments in Southern Oregon initiated in 1915 were planned[1] to determine definitely whether sulfur was responsible for increases obtained from sulfate-bearing fertilizers on alfalfa;[2] the value of various sulfates, and[3] whether sulfur acted directly as a plant food or indirectly as a stimulant and liberator of important elements of fertility. The experiment field is located seven miles north of Medford on antelope clay adobe soil.

Effect and value of sulfur fertilizer. Fertilizers containing phosphorus alone and those having this important plant food and sulfur also were applied in amounts calculated to provide the same number of pounds of elemental sulfur whatever sulfur-bearing compounds were used, as shown in Table V. These experiments seem to prove that increases obtained were due to sulfur in various applications and could be secured by use of elemental sulfur. Little increase was obtained from forms of phosphorus containing no sulfur. On this adobe soil alfalfa runs out after a few years and should be plowed up in five or six years. When sulfur is applied the stand endures longer than with no sulfur.

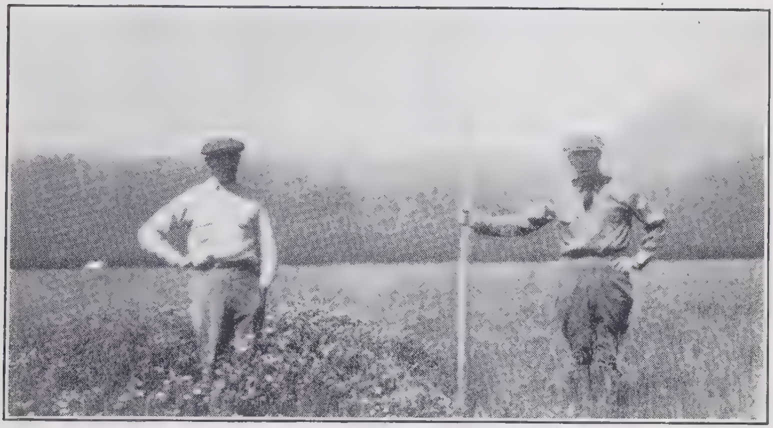

Fig. 8. Effect of sulfur on alsike, Fort Klamath.

This antelope clay adobe soil is well supplied with potassium, calcium, magnesium, organic matter, and calcium. It is low in phosphorus and very low in sulfur. It is neutral in reaction. When the experiment was started the alfalfa was two years old, thick, and had some nodules throughout.

Wherever sulfur or sulfates were applied, striking increases in yields were obtained, with fewer weeds. The elemental sulfur did not oxidize so as to become fully effective the first season. During recent years indication of need of supplementing the supply of phosphorus has increased. The larger yields secured by sulfur may be expected to hasten depletion of the low supply of phosphorus in this soil to a point where it will need to be supplemented. The results of this experiment show that the increase caused by sulfur is not due to liberation of phosphorus. The large amount of lime present in this soil favors oxidation of sulfur into available sulfates.

The east half of this 1915 series was retreated in March of 1917 and again in March, 1920. The west half of this series and others where not retreated have fallen off in yield the fourth and fifth years.

Duration and ultimate effect of treatment. This experiment at Medford, one of the older field experiments still under way, is of value as indicating the duration and ultimate effect of sulfur applications. The heavy applications of sulfur in this and other ranges of these experiment fields have shown no injurious effects from the applications, and the only apparent result has been increased yields. The soil is well supplied with calcium, and only the slightest indications of acidity can be found where heavy applications have been made. It is not to be expected that a simple element will permanently maintain fertility, and the time is likely to come when it will pay to supplement the supply of phosphorus and possibly other elements to give a permanent system of agriculture.

TABLE V. VALUE AND EFFECT OF SULFUR FERTILIZERS ON ANTELOPE CLAY ADOBE—OREGON EXPERIMENT STATION

1915 Series, Reimer Plots, Soil Experiment Field, Medford, 1915-1921. Yield per Acre, Tons. East ½ Retreated 1917-1920.

Treatment	Plot		1915	1916	1917	1918	1919	1920	1921	Alfalfa T. per A. 7 year Ave. 15-21 Inc.	Ave. Annual net gain from fertilizers	
											tons	
		E	1.495	.480	.380	.190	.560	.435	.520	.580	....	....
Check	1	W	1.495	.480	.380	.250	.400	.690	.610	.615	....	....
Gypsum												
595.0		E	5.440	4.920	3.040	1.070	2.440	3.250	2.145	3.180	2.524	$23.98
1 x 8 rds.	2	W	5.440	4.920	2.480	.570	2.790	1.590	1.160	2.707	2.097	20.55
Monocalcic												
phosphate		E	1.590	.710	.470	.260	.380	.670	.560	.663	0.001	–4.37
410.0	3	W	1.590	.710	.480	.270	.330	.410	.520	.616	0.006	–1.40
Superphos.		E	5.460	4.820	3.000	1.080	2.540	3.690	2.145	3.248	2.586	19.68
823.0	4	W	5.460	4.820	3.220	.580	2.760	1.380	1.065	2.755	2.145	19.39
		E	1.080	.335	.330	.350	.520	.725	.988	.620	....	....
Check	5	W	1.080	.335	.350	.280	.530	.660	.710	.563	....	....
Sulfur		E	2.640	5.270	3.700	1.150	3.110	3.350	2.868	3.155	2.493	24.06
100.0	6	W	2.640	5.270	3.920	.600	3.020	1.455	1.295	2.600	1.990	19.61
Sulfur		E	5.010	5.380	3.780	1.030	4.900	3.510	3.040	3.807	3.245	29.87
300.0	7	W	5.010	5.380	4.020	.850	4.580	4.765	3.995	4.086	3.476	33.90
Iron sulfate		E	5.610	5.780	4.480	1.360	3.990	2.340	4.410	3.996	3.334	32.54
842.0	8	W	5.610	5.780	4.160	.900	5.170	3.540	3.184	4.049	3.439	33.79
		E	1.085	.245	.760	.220	.380	1.700	1.110	.786	....	....
Check	9	W	1.085	.245	.760	.240	.380	.880	.985	.653	....	....

Value of fertilizers with and without sulfur (Table VI). The January, 1916 series (Table VI) was designed not only to learn the value of various elements with and without sulfur, but also to determine whether sulfur caused increased yield due to liberation of potassium or other elements. Plots 1 and 2 proved to be a shallow soil. Sulfur and sulfates continue to show large increases in this series. The more available sulfates work most promptly, and heavy applications gave larger increases the first year than light applications of sulfur. Applications of phosphorus, potassium, and nitrogen in available forms and in compounds free from sulfur gave little increase, while compounds containing these elements with sulfur or in sulfate form gave increases and good color similar to the results with sulfur alone. This fact shows that increased yields caused by sulfur were not due to liberation of other important plant foods.

Lime vs. sulfur. A new series of plots was started November, 1916 primarily to test the value of lime as compared to sulfur on this soil. Table VII gives the plan and results obtained. Use of lime has had no

TABLE VI. EFFECT OF FERTILIZER WITH AND WITHOUT SULFUR

January 1916 series: Reimer Plots, Oregon Experiment Station, Soil Experiment Field, Medford. Retreated 1920 except 6 and 17. Plot 9 received some sulfur bearing material probably 1920

	Treatment				
Plot	Fertilizer	Pounds per acre	Yield per acre Average for six years 1916-1921	Ave. gain in yield per acre	Ave. annual net gain from fertilizers
		lbs.	*tons*	*tons*	
1	Check	0	.493	-------	-------
2	Sulfur	600	2.036	1.502	$ 9.02
3	Sulfur	100	2.305	1.771	17.05
4	Sulfur	300	2.620	2.086	18.86
5	Gypsum	595	2.870	2.336	21.87
6	Mococo Residue (not retreated)	1541	2.725	2.191	17.41
7	Monocalcic Phosphate	317	.595	.061	–.97
8	Superphosphate	823	2.605	2.071	15.91
9	*Muriate of Potash (4 yrs. Some S '20)	534	1.165	.631	2.31
10	Sulfate of potash	594	2.445	1.911	13.17
11	Check	0	.545	-------	-------
12	Nitrate of Soda	558	.575	.041	–5.17
13	Sulfate of Ammonia	423	2.675	2.141	15.77
14	Iron sulfate	870	2.685	2.151	20.06
15	Magnesium sulfate	782	2.685	2.151	18.80
16	Sodium sulfate	1033	2.255	1.721	15.49
17	Pyrites (not retreated)	263	.890	.356	2.68
18	Check	0	.440	.094	-------

*4 yr. ave.

TABLE VII. COMPARISON OF LIME WITH SULFUR

November 1916 Series: Reimer Plots, Oregon Experiment Station, Soil Experiment Field, Medford

Plot	Treatment fertilizer	Amt. per acre	Cost	Ave.	Two	Yield per acre Alfalfa Ave. for 5 years 17-21	Incr.	Value	Net gain
		lbs.							
1	Check—harrowed	0	-------	-------	-------	.665	-------	-------	-------
2	Pyrites—harrowed	477	$2.38	$0.48	$0.96	1.485	.689	$6.86	$5.93
3	Pyrites—not harrowed	477	2.38	.48	.96	1.725	.929	9.29	8.33
4	Sulfur—not harrowed	100	2.00	.40	.80	2.925	2.129	21.29	20.49
5	Gypsum—not harrowed	595	4.47	.89	1.78	3.250	2.454	24.54	22.76
6	Quicklime—not harrowed	2000	10.00	2.00	4.00	.865	.069	.69	–3.31
7	Ground limestone—not harrowed	2000	5.00	1.00	2.00	.817	.026	.26	–1.74
8	Check—not harrowed	0	-------	-------	-------	.928	-------	-------	-------

Avg. Check .796

Plots retreated with same amounts of fertilizer in March, 1920. No yields are given for plots 7 and 8 for 1919 and hence the average yield is a four year average.

appreciable effect, showing that sulfur has not liberated this element for plants. Quicklime, like heavy sulfur applications, tends to mellow the surface soil but does not increase yields as does sulfur or sulfates. Due to early fall application this experiment gave time for oxidation, and much better results were secured the following growing season. Harrowing in pyrites applied on this heavy soil in the fall did not appear to hasten their action.

Sulfur and rock phosphate. Series of plots of antelope clay adobe were treated in the spring of 1917 and of 1919 to test the value of sulfur, sulfur and rock phosphate, gypsum, gypsum and rock phosphate, and superphosphate. The results of this experiment appear in Table IX.

Soil in plots 6 to 11 is slightly better than that in plots 1 to 5 inclusive. There is a growing indication of increase in yield where sulfur is supplemented by phosphate. Sulfur and rock phosphate applied together may aid prompt oxidation of sulfur and liberation of the phosphorus and ultimately prove more economical than acid phosphate.

TABLE VIII. COMPARISON OF SULFUR AND PHOSPHORUS
1917 Series: Reimer Plots, Oregon Experiment Station, Soil Experiment Field, Medford.

Plot	Treatment fertilizer	Amount per acre	Retreatments		Ave. yield per acre 6 yrs. 1917-22	Incr.	Value	Net gain
			4-15-19	3-1-20				
		lbs.	*lbs.*	*lbs.*	*tons*			
1	Check	0	0	0	.439	--------	--------	--------
2	Superphosphate	412	823	412	2.051	1.645	$16.45	$11.65
3	Gypsum	298	595	298	2.066	1.666	16.66	13.29
	Rock phosphate	281	564	281	--------	--------	--------	--------
4	Gypsum	298	595	298	1.937	1.531	15.31	13.82
5	Check	0	0	0	.345	--------	--------	--------
7	Superphosphate	412	823	412	2.238	1.832	18.32	11.64
	Rock phosphate	281	564	281	--------	--------	--------	--------
8	Sulfur	100	50	50	2.121	1.715	17.15	16.48
9	Sulfur	100	50	50	2.256	1.856	18.56	17.89
10	Sulfur	200	100	100	2.663	2.257	22.57	19.35
	Rock phosphate	281	564	281	--------	--------	--------	--------
11	Sulfur	200	100	100	2.043	1.637	16.37	15.33
12	Check	0	0	0	.435	--------	--------	--------

TABLE IX. COMPARISON OF SULFUR AND ROCK PHOSPHATE WITH SOLUBLE PHOSPHATE

1919 Series: Reimer Plots, Oregon Experiment Station, Soil Experiment Field, Medford.

Plot	Treatment fertilizer		Amount per acre	Yield per acre Average for 3 yrs. '20-'22		Increase	Value	Net
		lbs.			*tons*			
1	Check	0	--------	--------	1.540	--------	--------	--------
2	Superphosphate	412	$7.21	2.40	2.980	1.44	$14.40	$12.00
3	Sulfur	50	1.00	--------	--------	--------	--------	--------
	Rock phosphate	281	2.81	1.27	2.690	1.15	11.50	10.23
4	Sulfur	50	1.00	--------	2.561	1.021	10.21	6.88
5	Superphosphate	412	7.21	2.40	2.429	.889	8.89	6.49
6	Sulfur	50	1.00	--------	--------	--------	--------	--------
	Rock phosphate	281	2.81	1.27	2.389	.849	8.49	7.22
7	Sulfur	50	1.00	--------	2.020	.48	4.80	4.47

Treatment applied April 15, 1919.

Best rate of application. An experiment begun in 1917 by Professor Reimer on antelope clay adobe to determine the most profitable rate to apply sulfur is still being maintained. Results show (Table X) that on heavy soils the most economical returns may be expected from applying one hundred pounds an acre every three or four years.

In Deschutes fifty, eighty, one hundred, and two hundred pounds an acre, and in Union county fifty, one hundred, and two hundred pounds have been applied. One hundred pounds should meet requirements of increased yields for three to four years. On sandy soils in Deschutes Valley where, with heavy irrigation and rapid drainage, lighter and more frequent application is good practice, only sixty to eighty pounds every two or three years is necessary.

TABLE X. DIFFERENT RATES OF APPLICATION FOR SULFUR

1917 Sulfur Series, Reimer Plots, Oregon Experiment Station, Soil Experiment Field, Medford.

Plot	Treatment fertilizer	Amount per acre	Cost per acre	Yield per acre ave. for 3 yrs. 1918-21
		lbs.		*lbs.*
1	Sulfur	100	$2.00	2.063
2	Sulfur	200	4.00	2.290
3	Sulfur	300	6.00	2.173
4	Sulfur	400	8.00	2.123

Treated November, 1917.

No yield given for 1919 and hence the average is a three-year average although the series has run four years. All plots did not receive same amount of water, due to slope of land.

On some soils the initial application may help to establish alfalfa and overcome the deficiency so that a lighter treatment will suffice; or, in some cases, no retreatment may be required. Retreatment may be unnecessary on some acid red hill soils, and excessive amounts would tend to aggravate acidity.

Work on antelope adobe indicates that retreatments are needed each four years.

PROGRESS OF EASTERN OREGON EXPERIMENTS

Unfortunately the irrigation demonstration farm at Redmond was discontinued in 1913, but the fertilizer plots there gave similar yields and differences in 1913 as in the preceding year.

In the spring of 1913 one hundred pounds of commercial powdered sulfur was applied to one acre, with an increase in yield of nearly two tons an acre over adjoining, untreated, check plots.

In 1915 three one-acre plots in the Deschutes medium sand area were treated as above and on two of these, the Brown and Landis farms, practically two tons an acre increase was obtained each year for three years thereafter.

Effect of sulfur on various soils of Eastern or Central Oregon. (Table XI) Three fertilizer experiments were started on the Deschutes sandy loam in 1918. The plan and results covering a three-year period are given in Table XI. The second season of the trial appeared to be favorable for slightly larger yields, and the striking increases obtained from sulfur and sulfate treatments were slightly less apparent the third year of the experiment, indicating need of retreatment. The effect of sulfur has been much less the fourth year on this soil. Except in one field, these experiments were interrupted the fourth season, as a field agent could not be maintained. They proved that use of sulfur was applicable to the different project lands in Central Oregon.

Use of sulfur in comparison with gypsum (Table XII). Good gypsum contains about eighteen pounds of sulfur in one-hundred pounds of material in available form. Gypsum is mined near Huntington, Eastern Oregon, within a short distance of the Malheur, Powder, and Grande Ronde valleys, and is readily secured at most trading points in the state. Because it is readily secured and easy to apply, farmers have been inclined to continue its use under conditions where it is evidently effective

TABLE XI. EXPERIMENTS ON PROJECTS IN EASTERN OREGON

			Crop—Alfalfa '18, '19, '20. Avg. tons per acre	Avg. increase tons	3 yrs. Avg. Net value of increase
	Van Matre plots, Sisters, Ore.		*tons*	*tons*	
1	Muriate of potash	160	2.95	0.38	$1.00
2	Sulfate of potash	160	3.10	0.53	0.50
3	Sulfur	100	3.51	0.94	7.40
4	Check	0	2.57	------	------
5	Superphosphate	320	3.22	0.65	0.90
6	Nitrate of soda	80	3.14	0.57	3.30
7	Check	0	2.57	------	------
8	Gypsum	50	3.05	0.48	4.55
	Becker plots, Tumalo				
1	Gypsum	50	2.74	0.85	8.25
2	Muriate of potash	160	1.95	0.06	–4.60
3	Superphosphate	320	2.39	0.50	–0.60
4	Nitrate of soda	80	2.32	0.43	1.90
5	Sulfate of potash	160	2.85	0.96	4.80
6	Sulfur	80	2.97	1.08	9.20
7	Check	0	1.89	------	------
	Martin plots, Redmond				
1	Check	0	4.07	------	------
2	Muriate of potash	160	4.07	0.00	------
3	Superphosphate	320	5.02	0.95	4.70
4	Nitrate of soda	80	5.14	1.07	5.10
5	Sulfate of potash	160	5.78	1.71	12.30
6	Sulfur	80	5.96	1.89	17.30

TABLE XII. COMPARISON OF SULFUR VS. GYPSUM
Deschutes Valley Sandy Loam Soils

	Treatment		
Plot	Fertilizer	Amount per acre	Yield, tons per acre
Alfalfa	W. B. Chapman—2 miles north of Redmond, 1918.		
		lbs.	*tons*
1	Sulfur	80	1.44
2	Check	0	.70
3	Gypsum	50	1.36
	H. Solburg—3 miles northwest of Redmond.		
1	Sulfur	40	1.88
2	Gypsum	50	1.51
	Brown—3 miles north of Tumalo.		
1	Sulfur	------	2.69
2	Gypsum	------	2.08
	P. J. Peterson—Grange Hall.		
1	Sulfur	160	2.30
2	Gypsum	50	1.54
Alfalfa	M. E. Landes—2 miles west of Redmond, 1918.		
1	Sulfur	------	5.44
2	Check	------	2.38
3	Gypsum	------	2.79
Alfalfa	E. Atkinson—2 miles southwest of Redmond, 1919.		
1	Sulfur	80	2.55
2	Check	0	1.05
Alfalfa	W. R. Davidson—Terrebone, 1919.		
1	Sulfur	100	6.50
2	Gypsum	50	5.39
Alfalfa	H. Solberg—3 miles northwest Tumalo.		
1	Sulfur 1918	40	1.15
2	Sulfur 1919	------	1.70
	Average		
1	Sulfur	------	3.26
2	Gypsum	------	2.45
3	Check	------	1.38

in supplying available sulfur. The disagreeable feature of applying sulfur can be largely overcome by mixing it with damp sand just before the application is made; it can then be applied with a land-plaster spreader.

In the spring of 1918 seven demonstration experiments, in addition to the Eastern Oregon experiments just reported, were started in the Deschutes Valley on medium sandy loam to test further the value of sulfur as compared with gypsum. Unfortunately these experiments were located on various ranches, and accurate yields were not obtained after the first season. The plan of these trials and yields is given in Table XII. Applications were made before alfalfa began growth. The alfalfa was usually renovated and was irrigated so that the sulfur became rapidly oxidized, and sulfur plots frequently out-yielded the gypsum plots the first season.

Rate and form of application. Six cooperative demonstration experiments were conducted in Union county by County Agent Paul Spillman. Applications to alfalfa plots were made in the spring of 1917, gypsum being applied at the rate of fifty, one hundred, two hundred, three hundred pounds to an acre and sulfur at the rate of one hundred and two hundred pounds an acre. Three fields employed were clay loam, two were dark silt loam, and two were sandy loam soils. Only one of the soils received irrigation, and, as the first season was a dry one, results were secured from only the irrigated field. A dark silt loam soil employed belonged to Mr. Homer Carnes, located near North Powder. Two hundred pounds of sulfur increased the yield three hundred pounds, while a like amount of gypsum increased the yield 450 pounds the first season. A hundred-pound application of sulfur gave a season's increase in yield of 612 pounds, while a hundred-pound application of land-plaster gave an increased yield of 797 pounds. The following year all seven trials gave substantial increases from applications of sulfur and sulfate. Accurate yields were not obtained after the second year. The results show greatest profits from using 200 pounds of gypsum or 100 pounds of sulfur on alfalfa meadows. By 1920 it was found that the fifty-pound and one-hundred-pound applications of gypsum caused little appreciable increase in growth, while the increase in yield for two-hundred- and three-hundred pound applications was still apparent and the one-hundred- and two-hundred-pound applications of sulfur were still giving marked increases. The fifth season the increase from the sulfured plots appeared to be as marked as in previous years, while the gypsum treatment had run out. Data of the first two seasons show that the gypsum was most effective in the season of 1918, but the sulfur had become most effective by 1919, showing that it is the more economical and permanent treatment.

As an average of all trials to and including 1920, sulfur applications in the Deschutes Valley have given a net profit of $18.00 over untreated plots, while gypsum has given an increased net profit of $6.50 or less than half as much. These results emphasize the need for sulfur.

New fertilizer experiments in Eastern Oregon (Table XIII). A fertilizer experiment was initiated on Deschutes medium sandy loam in the spring of 1921 planned with the sulfur problem in mind and arranged to include a series of plots cropped to alfalfa for rotation with others receiving similar treatment and cropped to grain and potatoes. The plan of experiments and the results obtained are summarized in Table XIII. This soil is medium sandy loam of medium depth. A light application of gypsum had been used to start the alfalfa. This lessened the results from sulfur the first year. The liberal amount of irrigation used and the limited quantity and percent of plant food tend to lessen the duration

TABLE XIII. RECENT FERTILITY TRIALS IN DESCHUTES VALLEY, EASTERN OREGON

Deschutes sandy loam, Adams tract, Redmond

		Rate per acre	Cost of treatment	Yield per acre		Two-year increase from fertilizer	Net value* two-year increase
				1921	1922		
Alfalfa							
		lbs.		*tons*	*tons*		
1	Check	......	......	2.70	3.59	......	......
2	Sulfur	100	$2.00	2.99	3.84	.48	2.30
3	Gypsum	200	1.50	2.96	3.70	.26	1.10
4	Rock phosphate	600	6.00	2.98	3.68	.26	–3.40
5	Triple phosphate	100	2.50	3.01	3.71	.32	.70
6	Check	......	......	2.81	3.74	......	......
7	Potassium chloride	100	3.50	3.02	3.98	.60	2.50
8	Potassium sulfate	100	3.50	3.02	4.57	1.19	8.40
9	Nitrate of soda	100	3.50	2.83	3.74	.17	–1.80
10	Ammonium sulfate	200	8.00	3.04	3.91	.55	–2.50
11	Check	......	......	2.80	3.57	......	......
12	Sodium nitrate	100	3.50	3.05	3.86	.51	–2.60
	Potassium chloride	100	3.50	......	......	......	......
13	Sodium nitrate	100	3.50	2.97	3.69	.26	–.90
	Triple acid phosphate	100	2.50	......	......	......	......
14	Potassium chloride	100	3.50	3.02	3.91	.53	1.80
	Triple acid phosphate	100	2.50	......	......	......	......
15	Triple acid phosphate	100	2.50	2.99	3.72	.31	.60
	Potassium chloride	100	3.50	......	......	......	......
	Sodium nitrate	100	3.50	......	......	......	......
16	Check	......	......	2.78	3.65	......	......
17	Sulfur	100	2.00	2.95	......	.18	–.20
	Manure	10T	......	......	......	......	......
18	Rock phosphate	600	6.00	2.98	......	.21	–3.90
	Manure	10T	......	......	......	......	......
Average of checks		......		2.77	3.63	......	......
Potatoes				*bu.*			
1	Check	......	......	82	225	......	......
2	Sulfur	100	2.00	98	245	38	20.80
3	Gypsum	200	1.50	103	244	42	22.70
4	Rock phosphate	600	6.00	100	245	40	18.00
5	Triple acid phosphate	100	2.50	88	249	32	16.70
6	Check	......	......	69	223	......	......
7	Potassium chloride	100	3.50	119	250	64	34.90
8	Potassium sulfate	100	3.50	116	244	60	32.50
9	Nitrate of soda	100	3.50	103	249	47	24.70
10	Ammonium sulfate	200	8.00	118	253	66	34.60
11	Check	......	......	91	233	19	11.40
12	Sodium nitrate	100	3.50	105	245	45	23.50
	Potassium chloride	100	3.50	......	......	......	......
13	Sodium nitrate	100	3.50	112	246	53	28.30
	Triple acid phosphate	100	2.50	......	......	......	......
14	Potassium chloride	100	3.50	117	247	59	31.90
	Triple acid phosphate	100	2.50	......	......	......	......
15	Triple acid phosphate	100	2.50	119	250	64	35.90
	Potassium chloride	100	3.50	......	......	......	......
	Sodium nitrate	100	3.50	......	......	......	......
16	Check	......	......	87	233	15	9.00
17	Sulfur	100	2.00	......	......	......	......
	Manure	10T	......	......	......	......	......
18	Rock phosphate	600	6.00	......	......	......	......
	Manure	10T	......	......	......	......	......
Average of checks		......	......	77	228	......	......

*Hay at $10.00 per ton. Potatoes at 50c per bu.

of the sulfur treatment. Comparatively light, frequent applications of sulfur and sulfate fertilizers will consequently be most economical. In recent years there is also a growing indication that in time potash will need to be supplied. This soil responds to nitrogen unless it is supplied by rotation with legumes. During seven seasons' fertilizer experiments with potatoes conducted in this section potash has been found to pay well. The form of potash fertilizer that has paid best has been sulfate of potash. Ammonium sulfate on non-legume sod has given good results; where increase has been obtained from the use of sulfur or ammonium sulfate, the results may be partly due to the checking of potato scab. Nitrogen can be obtained under Deschutes Valley conditions by rotation with legumes. Sulfur can be obtained more cheaply in elemental form.

TABLE XIV. SUMMARY OF FERTILIZER TRIALS, DESCHUTES VALLEY, EASTERN OREGON

Trials mainly in 1912 and 1918, 1919, 1920. Oregon Experiment Station Department of Soils. Four-year average.

Fertilizer	Crop	No. of trials	Ave. rate per acre		Ave. yield per acre	Average increase over check plot	Net value* of increase
			Applied	Value			
Sulfur	Alfalfa	8	80	$3.20	4.35	1.8 T.	$18.00
Sulfur	Oats	1	80	3.20	30 bu.	5 bu.	.80
Gypsum	Alfalfa	10	52.5	.37	3.75 T.	.67 T.	6.51
Phosphorus	Alfalfa	6	280	5.12	3.95 T.	1.10 T.	8.44
Phosphorus	Barley	1	320	5.12	66.2 bu.	3.40 bu.	1.30
Nitrogen	Alfalfa	6	80	3.20	4.00 T.	1.14 T.	9.80
Nitrogen	Barley	1	160	6.40	69 bu.	8.4 bu.	3.05
Manure	Barley	1	10 T	--------	61.7 bu.	1.1 bu.	
Muriate of potash	Alfalfa	4	140	13.90	3.09 T.	.62 T.	6.20
Muriate of potash	Potatoes	7	130	11.55	113 bu.	24. bu.	8.10
Sulfate of potash	Clover	1	160	14.40	5.04 T.	1.71 T.	10.90
Sulfate of potash	Alfalfa	2	120	8.75	5.23 T.	1.33 T.	8.92
Sulfate of potash	Potatoes	11	160	14.40	235 bu.	90 bu.	40.20
Kemfert	Potatoes	7	126	7.94	94.4	7.6 bu.	–3.76
Kelpchar	Potatoes	4	240	15.15	98.5	25.72 bu.	–1.54

* Hay at $10.00 per ton. Potatoes at 50c per bu.

Cost, value, and profit from fertilizers used in Deschutes Valley, Eastern Oregon (Table XIV). A summary of all representative fertilizer trials in the Deschutes Valley is given in Table XIV. This table is arranged to show the cost, value, and profits from fertilizer treatments, using the market prices for fertilizers and products. The largest profit has been realized from potash on potatoes, the next largest net profit an acre has been realized from the use of sulfur on alfalfa. Sulfur trials have been made on most of the alfalfa soils in the state and nearly all of the important alfalfa areas respond to sulfur to a marked extent. There appears to be little relation between soil texture and reaction from sulfur treatment. Free working soils perhaps oxidize a little more sulfur and the results seem to be a little more rapid on such land. Under irrigation, however, the duration of the sulfur treatment is not so long on sandy as on the heavy-textured soils. There does appear to be a fairly close relation between the sulfur content of soils and their response to sulfur treatment. These experiments were retreated and extended at the beginning of the growing season of 1923 to study the effect of different forms of sulfur and different rates of application.

Sulfur versus potassium. The results as summarized for recent experiments for Deschutes Valley sandy loam indicate that sulfur is having some effect on the liberation of potassium. This is also indicated by certain recent observations on Willamette silt loam. Composts with these soils have been prepared in the laboratory to test the effect of different rates of sulfur and gypsum on solubility of mineral plant food.

SULFUR FERTILIZERS ON VARIOUS SOIL TYPES

Sulfur fertilizer trials have been conducted on some two dozen of the leading soil types of Oregon, with results as summarized in Table XV. These trials indicate that at least 100,000 acres of alfalfa in Oregon could be profitably sulfured. Another area of equal size which could be used for alfalfa in rotation should respond equally well. The soils responding range from fine sand to clay adobe. Some soils in the humid sections, notably the older grain lands in the lower Willamette Valley and the red hill lands, appear to be in need of sulfur in many cases.

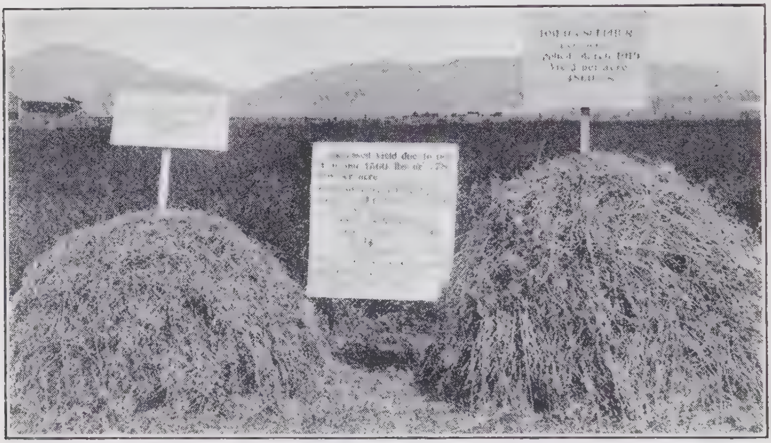

Fig. 9. Effect of sulfur on Klamath Project soil.

Soils which do not respond to sulfur. A few soils have been found which do not appear to need sulfur. Medford loam and peat or muck soils, being well supplied with vegetable matter, contain a large sulfur supply. Medium and coarse sand in Umatilla basin receives nearly sufficient sulfur from the large applications of irrigation water applied and has given increases in but few cases. Willamette silty clay loam in the upper Willamette Valley contains 600 to 700 pounds of sulfur in an acre to plow depth, and since this sulfur oxidizes readily little increase is obtained from sulfur applications.

Correspondence with experiment stations and a study of station literature throughout the United States, and of rock composition, lead to the view that the basaltic soils of the Northwest offer the greatest field for profitable use of sulfur on soil in the United States.

TABLE XV. ALFALFA YIELDS WITH AND WITHOUT SULFUR ON VARIOUS SOILS OF OREGON

	Soil	Location and farm	No. of plots	Treatment		Annual avg. yield per acre	Average gain from treatment
				Kind	Amt. per acre		
1	Antelope clay adobe	Bernst,	10	None	--------	0.57	--------
		Medford	1	Gypsum	297.5	2.172	2.440
			4	Sulfur	100.0	2.678	2.108
2	Medford fine sandy loam	M. Hanley,	1	None	0.0	2.405	--------
		Jacksonville	1	Gypsum	300.0	3.875	1.470
			1	Sulfur	300.0	3.460	1.055
3	Tolo loam	Frame,	2	None	0.0	1.142	--------
		Talent, Oregon	1	Gypsum	590.0	1.908	0.766
			1	Sulfur	100.0	1.283	0.141
4	Phoenix clay adobe	Barneburg,	2	None	0.0	1.549	--------
		Medford	1	Gypsum	595.0	3.552	2.002
			1	Sulfur	100.0	2.284	0.734
5	Medford gravelly clay loam	Hartley,	6	None	0.0	1.110	--------
		Talent, Oregon	2	Sulfur	300.0	1.970	0.860
6	Salem clay loam	Hanley,	3	None	0.0	1.305	--------
		Medford	1	Gypsum	595.0	3.654	2.349
			1	Sulfur	100.0	3.862	2.557
7	Coleman gravelly clay loam	Schnebley,	3	None	0.0	0.535	--------
		Phoenix, Ore.	1	Gypsum	595.0	1.270	0.735
			1	Sulfur	100.0	1.090	0.555
8	Barron coarse sand	Schneider,	2	None	0.0	1.314	1.088
		Ashland	1	Gypsum	374.0	2.401	--------
9	Salem fine sandy loam (coarser phase)	Modoc Orchard	1	None	0.0	0.760	--------
		Table Rock	--	Gypsum	200.0	1.800	1.040
			--	Sulfur	200.0	1.530	0.770
10	Willamette silt clay loam	Ore. Exp. Sta.	10	None	0.0	5.00	--------
		Corvallis	10	Sulfur	100.0	5.04	.04
11	Umatilla medium sand	Br. Exp. Sta.	2	None	0.0	3.064	--------
		Supt. Dean	2	Sulfur	200.0	3.912	.848
			2	Gypsum	200.0	3.690	.626
12	Umatilla fine sand	Stanfield	2	None	0.0	4.95	--------
		C. W. Connor	2	Sulfur	100.0	6.38	1.32
13	Fine sandy loam	Boardman	2	None	0.0	5.50	--------
		Mr. Cobb	2	Sulfur	--------	6.25	0.75
14	Deschutes sandy loam	All exp. fields	8	None	0.0	3.00	--------
			10	Gypsum	60.0	4.73	1.73
			8	Sulfur	100.0	4.02	1.02
15	Very fine sandy loam	Dufur	2	None	0.0	1.50	--------
		M. M. Burtner	2	Sulfur	100.0	4.00	2.5
16	Dark loam	Union Station	8	None	0.0	6.43	--------
		Supt. Withy-	2	Sulfur	--------	7.08	.625
		combe	2	Gypsum	--------	7.24	.780
17	Dark loam	Carnes	4	None	--------	2.50	--------
		N. Powder	4	Sulfur	100.0	4.00	1.50
18	Dark loam	Vale	2	None	--------	2.29	--------
		Russell	2	Sulfur	100.0	2.41	.12
19	------------------------------	Harney Br. Sta.	2	None	--------	4.91	--------
		Supt. Shattuck	2	Sulfur	100.0	5.10	.19
20	Sandy loam	J. F. Hansen	6	None	--------	1.50	--------
		Lakeview	6	Sulfur	100.0	3.00	1.50
21	Klamath clay loam	Klamath	5	None	--------	1.20	--------
		Nelsons	5	Sulfur	100.0	3.26	2.06
22	Yakima sandy loam	McClay	1	None	--------	3.30	--------
		Klamath	1	Sulfur	100.0	4.86	1.56

Effect of sulfur on different crops (Table XVI). The yields of crops included in sulfur fertilizer trials is compiled in Table XVI. The legumes responding well to sulfur in order of increase are alfalfa and red and alsike clover. A number of crops of the legume and the cabbage

TABLE XVI. EFFECT OF SULFUR ON VARIOUS CROPS

Crop	Soil	Location and cooperator	Number of trials	Kind	Amt. per acre	Annual yield per acre	Gain from treatment
						(*Tons unless indicated*)	
Red clover	Agate gravelly sandy loam	Hilton, Medford	1	None	0	2.340	-------
			1	Gypsum	590	3,625	1.255
			1	Sulfur	100	4.740	2.400
Red clover	Agate gravelly loam	Rogue River	1	None	0	0.285	-------
			1	Gypsum	600	0.608	0.323
			----	Sulfur	105	0.825	0.540
Red clover	Willamette silty clay loam	O. A. C. Exp. Sta. Corvallis	7	None	0	4.855	-------
			7	Sulfur	320	6.500	1.645
Red clover seed	Carlton clay loam	Abraham No. Albany	3	None	0	197.0 lbs.	-------
			1	Sulfur	150	280.0 lbs.	83.0 lbs.
Red clover and timothy (manured)	Red hill	Astoria Br. Station Supt.	3	None	0	3.48	-------
			1	Sulfur	200	4.05	0.57 T
Alsike clover and timothy	Medium peat	Klamath F. McCormack	2	None	0	2.18	-------
			2	Sulfur	100	2.32	0.14 T
Field peas	Sandy loam	Klamath W. Johnston	----	None	0	3.92	-------
			----	Sulfur	200	3.92	0.00 T
Field peas	Very fine sandy loam	Harney Br. Exp. Station Supt. Shattuck	.	------- ----	-- --	5.50	-------
			----	---------------	------	5.70	.20 T
Field peas	Antelope clay adobe	---------- ---- ---------	----	---------------	------	.90	-------
		-----------------------------	----	---------------	------	1.00	.10 T
Peas and oats	Melbourne silty clay loam	Astoria Br. Exp. Station	3	None	------	2.00	-------
			1	Sulfur	200	2.325	.325 T
Peas and oats (silage)	Dark loam	Union Br. Exp. Station Supt. Withycombe	8	None	------	7.14	-------
			2	Sulfur	100	7.22	–.08 T
Field peas	Very fine sandy loam	Harney Branch Exp. Station	1	None	------	27.6 bu.	-------
			1	Sulfur	100	32.6 bu.	5.00 bu.
White beans	Dayton silty clay loam	Ore. Exp. Sta. Corvallis	4	None	------	11.0 bu.	-------
			1	Gypsum	100	1.0 bu.	0.0 bu.
Soy beans	Antelope clay adobe. Med soil	Exp. Field	----	None	------	816.0 lbs.	-------
			----	Sulfur	100	944.0 lbs.	128.0 lbs.
			----	Gypsum	250	1255.0 lbs.	439.0 lbs.
Oat hay	Powell silt loam	Corbett-Salzman	1	Manure	10 T	1.34	-------
			1	Sulfur and manure	100 lbs. and 10 T	1.57	.23
Oat hay	Willamette silty clay loam	State Exp. Sta. tanks Exp.	2	None	------	39 grams	-------
			2	Sulfur	100 lbs.	49 grams	10.0 grams
Oat hay	Deep peat	Lake Labish	1	None		10.5 grams	

	adobe	Exp. Field	1	Sulfur	100	24.4	bu.	10.9	bu.
Barley	Deschutes sandy loam	Redmond	2	None	......	21.5	grams	......	
		Tank Exp.	2	Sulfur	100	32.0	grams	10.5	grams
Barley	Willamette silty clay loam	O. A. C. Exp.	2	None	......	66.9	bu.	......	
		Sta. Corvallis	2	Sulfur	320	60.9	bu.	-6.0	bu.
Barley	Newberg silt loam	Ore. Exp. Sta.	....	None	......	26.4	bu.	......	
		Corvallis	....	Sulfur	160	28.7	bu.	2.3	bu.
Barley	Mellan very fine sandy loam	Ontario	3	None	......	80.45	bu.	......	
		T. W. Claggett	2	Sulfur	100	81.50	bu.	1.05	bu.
Barley	Very fine sandy loam	Harney Br. Exp.	....	None	......	56.40	bu.	......	
		Sta. Supt. Shattuck	1	Sulfur	100	69.10	bu.	12.7	bu.
Wheat	Willamette silty clay loam	O. A. C. Exp.	7	None	......	46.4	bu.	......	
		Sta. Corvallis	2	Sulfur	320	51.2	bu.	4.8	bu.
Wheat	Carlton silty clay loam	Abraham	4	None	......	12.5	bu.	......	
		No. of Albany	1	Sulfur	150	20.5	bu.	8.0	bu.
Wheat	Very fine sandy loam	Br. Exp. Sta. Moro	8	None	......	41.4	bu.	......	
		Supt. Stevens	2	Sulfur	100	42.4	bu.	1.0	bu.
Wheat hay	Dark loam	E. Ore. Br. Exp. Sta.	4	None	......	2.27		......	
		Supt. Withycombe	1	Sulfur	100	2.36		.09	T
Wheat	Very fine sandy loam	Harney Br. Exp. Sta.	2	None	......	63.60	bu.	......	
		Supt. Shattuck	1	Sulfur	100	58.40	bu.	-5.2	bu.
Corn	Willamette silty clay loam	O. A. C. Exp. Sta.	14	None	......	6.37		......	
		Corvallis	4	Sulfur	320	6.80		.57	T
Corn	Newberg sandy loam	O. A. C. Exp. Sta.	42	None	......	4.69		......	
		Corvallis	6	Sulfur	320	4.16		-.53	T
Corn	Olympic silt loam	Shaw	4	None	......	7.20		......	
		C. J. Gilbert	1	Sulfur	100	9.40		2.20	T
Corn	Powell silt loam	Corbett-	2	None	......	11.05		......	
		Salzman	1	Sulfur	100	11.99		.94	T
Corn	Dark loam	E. Ore. Ex. Sta.	4	None	......	10.50		......	
		......	1	Sulfur	100	12.00		1.50	T
Corn	Malheur, very fine sandy loam	Ontario	....	......	......	......		......	
		T. W. Claggett	....	......	......	......		......	
Potatoes	Yakima sandy loam	Klamath Proj.	1	None	......	250.0	bu.	......	
		S. E. Heseltine	1	Sulfur	100	249.3	bu.	.3	
Potatoes	Deschutes sandy loam	Redmond Exp.	7	None	......	107.4	bu.	......	
		Sta. C. A. Adams *et al.*	2	Sulfur	100	125.4	bu.	18.0	
Potatoes	Powell silt loam	Corbett-	2	None	......	181.5	bu.	......	
		Salzman	1	Sulfur	100	235.8	bu.	54.3	
Beets	Very fine sandy loam	Harney Br. Exp.	2	None	......	5.8		......	
		Sta. Supt Shattuck	2	Sulfur	100	5.5		-.3	T
Kale	Willamette silty clay loam	Ore. Exp. Sta.	7	None	......	13.1		......	
		Corvallis	2	Sulfur	320	15.8		2.7	T

families were included in a trial in 1920 and 1921 to test the effect of sulfur and gypsum when grown on antelope clay adobe. The effect of sulfur on field peas, so far as tried, is not striking. On antelope clay adobe soy-beans yielded 816 pounds an acre unfertilized in 1920. With one hundred pounds of sulfur an acre the yield was 944 pounds, and with 250 pounds of gypsum an acre the yield was 1255 pounds.

Among the cereals, oats required most sulfur. Some moderate increases have been secured from sulfur with wheat and corn. Sulfur applied to kale and rape on Willamette silty clay loam at Corvallis in 1913 failed to give an increase in yield. Kale and sunflowers fail to respond to sulfur.

TABLE XVII. 1921 SERIES. INOCULATED SULFUR VS. UNINOCULATED SULFUR

Antelope clay adobe, Southern Oregon Soil Experiment Field. Seeded 1920. Treated July 14, 1921. Yield pounds per acre.

Plot		1921 Last cutting	1922 First cutting	1922 Second cutting	Tons for yr.
1	Check	1215	2830	1180	2.065
2	100 pounds to the acre Inoculated sulfur	1215	3410	1540	2.475
3	100 pounds to the acre Sulfur	1115	3735	1540	2.135
4	Check	1180	3035	1425	2.230

TABLE XVIII-A. VALUE OF SULFUR IN CONNECTION WITH MANURE AND ROCK PHOSPHATE

1920 Series: Oregon Experiment Station, Soil Experiment Field, Medford.

Plot	Treatment Fertilizer	Treatment Amount per acre	Cost	Yield per acre —Average for 2 years—1920, 1922— *tons*	Incr. S.		Net
	Manure	20 T	--------	--------	--------	--------	------
1	Sulfur	100 lbs.	$2.00	2.31	1.055	$10.55	9.55
	Manure	20 T	--------	--------	--------	--------	------
	Sulfur	100 lbs.	2.00	--------	--------	--------	------
2	Rock phosphate	281 lbs.	2.81	2.225	.970	9.70	7.30
3	Manure	20 T	--------	1.255	--------	--------	------
4	Check	0	--------	.565	--------	--------	------

Treatments applied September, 1920.

TABLE XVIII-B. VALUE OF SULFUR IN MAKING PHOSPHORUS AVAILABLE

Cascade silt loam (hill phase) Multnomah county.

Treatment Kind and rate per acre	Yield per acre tons Corn 1920	Potatoes 1921	October hay—1922 No lime	October hay—1922 Limed 1½ tons an acre
Untreated check plots, average	11.047	5.445	.975	1.263
Sulfur 100 lbs.	11.987	7.074	.957	.891
Manure 10 tons	11.918	5.895	1.343	1.436
Sulfur + manure 10 tons	12.946	8.910	1.569	1.584
Superphosphate 250 lbs.	12.591	6.525	1.091	1.197
Rock phosphate 500 lbs.	11.613	5.670	.9609	1.157
Sulfur 100 lbs. + rock phosphate 500 lbs.	---------	---------	.944	1.277
Sulfur 100 lbs. + rock phosphate 500 lbs. + manure 10 tons	---------	---------	1.197	1.569

Value of activated or inoculated sulfur (Table XVII). Practically all the striking results obtained from sulfur as a fertilizer in Oregon have been secured with uninoculated ground sulfur. The bacteriologists of the Oregon Station find that many Oregon soils contain a plentiful supply of sulfofying bacteria, and that sulfur oxidizes at a more rapid rate than required by crops. Under severe or unfavorable climatic or soil conditions it is necessary to apply sulfur several weeks before growth begins, and it is generally helpful to harrow it in, or use some gypsum the first season with late applications.

In the spring of 1921 a supply of activated sulfur was secured through the courtesy of Dr. Jacob Lipman, director of the New Jersey Experiment Station, for use in field trials at Medford and Hermiston. Further trials have since been added at the branch station at Union, Oregon. No definite response from sulfur was obtained at Hermiston Station even when used with manure or activated, until the present year, when the spring rain lessened the amount of early irrigation. At Medford some advantage was gained in point of time by use of inoculated sulfur.

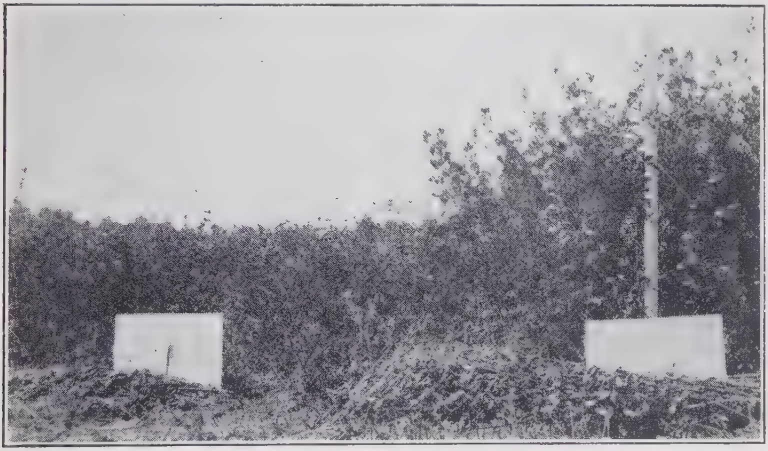

Fig. 10. Effect of sulfur, Deschutes Valley trials.

VALUE OF SULFUR AND SULFATES IN RESTORING STRUCTURE OF DRAINED ALKALI LAND

Many years ago Dr. Hilgard[23] suggested the application of calcium sulfate or gypsum to black alkali for converting it into soluble form in the soil so that it could be "laundered" out following drainage by copious irrigation. Dr. Scofield[24] more recently has proposed the use of aluminum sulfate to prevent the running together of land containing black alkali, and has suggested that this running together is due to the action of soda salts on the silicate in the soil, causing the development of colloidal sodium silicate, or water-glass. Aluminum being trivalent, rapidly setting free the sulfuric acid in the soil, is looked to by him as a permanent corrective for breaking up or overcoming this colloidal condition. Some interesting results with sulfuric acid were obtained by Dr. Lipman[8] in California experiments.

In 1918 and 1919 sulfur applications were used on sweet clover seedings on land affected with alkali near Klamath and Ontario. There was an improved growth of sweet clover, which was calculated to add green manure and loosen the soil. There was apparently an improvement in the structure of the land, which was given copious irrigation.

Improvement of alkali land is regarded as one of the larger soil problems in Eastern Oregon, and has been made the object of special investigation during the past three seasons. Experiments outlined by the writer and placed in charge of W. W. Johnston of the Soils department will be reported in detail later. Since good progress has been made, these experiments are here briefly referred to.

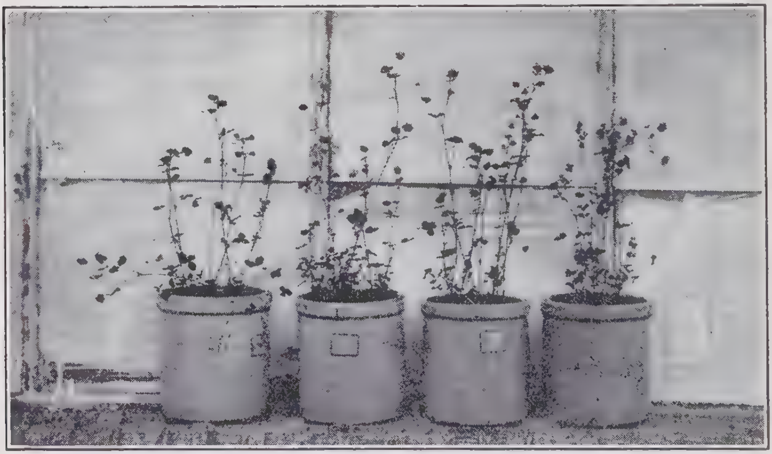

Fig. 11. Effect of sulfate on clover nitrification.
1 Untreated. 2 Lime. 3 Lime and sulfur. 4 Sulfur.

A ten-acre tract was selected near Vale at the beginning of the season 1921, having a mixed growth of sagebrush and greasewood, being situated within reach of an outlet into the river channel. A ditch was started with the use of a V-grader, Fresno scraper. A stream of water amounting to 4 or 5 cubic feet a second was then run through, while the soil was scarified by means of a one-horse cultivator. This sluicing method proved to be an economical method of building ditches, and a local farmer, Mr. Purvis, perfected a scarifying tool similar to a thresher cylinder to facilitate this process.

The experimental tract was then cleared and checked for irrigation and sampled. It was divided into some twenty half-acre plots, treated with different amounts of sulfur, gypsum, gypsum and manure, and aluminum sulfate. Straw cover and sweet clover straw containing matured seed were also employed. The land was given copious irrigation the first season, amounting to a total depth of 48 to 60 inches. A large proportion of the soluble white alkali was removed during this first season's flushing, as indicated by determinations at the end of the season. Sweet clover and rye were planted and a spotted crop secured the following summer. The amount of black alkali was not substantially reduced, and except with the heavy sulfate treatments, it largely remained in the land, while on an average more than a ton an acre of total salts was washed out of the land.

Flushing was continued through the second season. Percolation was found to proceed better, particularly on treated plots due to improved structure. A large part of the black alkali was removed where sulfates were applied. This soil is well supplied with calcium. Rye and sweet clover were again seeded, and where the best treatments have been employed a fair crop is being secured.

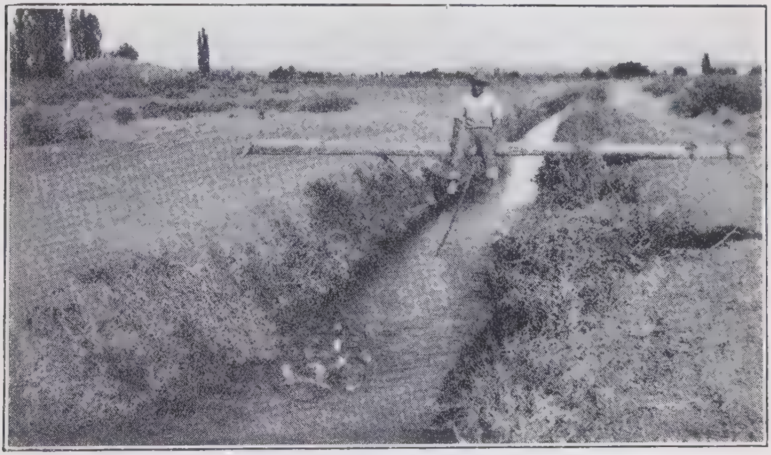

Fig. 12. Purvis sluicing machine.

The bearing strength of bricks made of this soil in the laboratory, sun dried and tested in the engineering laboratory, have been found to be reduced about one-half with certain sulfate treatments, particularly heavy applications of gypsum and manure.

The seeding of ditched, uncleared land appears to be advantageous during the flushing process, and some native and volunteer growths offer opportunity for pasture during reclamation, thus reducing expense. Eight dollars' worth of sulfur made possible a ton of rye an acre where nothing grew before. Field work is checked by tank work in the greenhouse where rye and sweet clover have been grown with fair success on tanks given sulfate treatment, a maximum growth occurring on tracts receiving heavy application of alum, sulfur, gypsum, or manure. The leaching process in the field has removed a quarter to a third of the nitrate and sulfate content of this soil. Trials with ammonium sulfate and other applications for replenishing fertility are under way. Detailed data will be the subject of another report.

Value of sulfur in aiding solubility of phosphorus (Table XVIII). Sulfur rock-phosphate composts have been studied by Lipman[26] and others for making phosphate available. Field trials have been conducted in recent years to test out the practicability of applying sulfur and ground raw rock phosphate for maintaining supply of these elements in certain Oregon soils. Two of the experiments for which there is more than one year's record are reported in Table XVIII.

Experiments started on antelope clay adobe in the spring of 1919 (Table XVIII-a) were planned to test the value of sulfur and manure in making available phosphorus in raw rock phosphate. The experiment gives indication that the treatment will prove economical. The soil is giving marked response to barnyard manure.

In experiments on the Carlton silty clay loam in Benton county (Table XVIII-b) and Cascade Powell silt loam in Multnomah county in the humid sections, sulfur, rock phosphate, manure, and lime have given some of the largest yields. Lime, however, was added at another time in the rotation than was the sulfur.

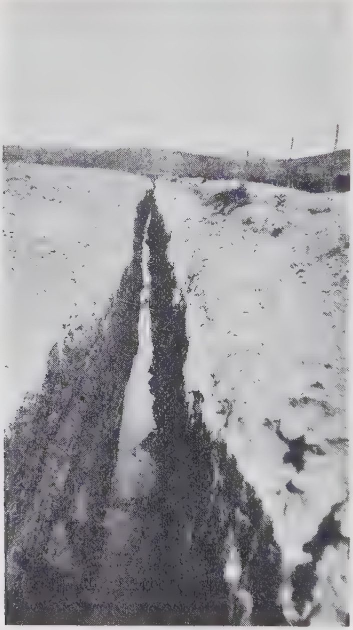

Fig. 13. Ditch made with Purvis sluicer.

Composts prepared by Professor C. V. Ruzek to study liberation of phosphate in red hill soils were made to include sulfur at the suggestion of the writer. These studies will be a subject for a separate report. The effect of sulfur in this study is briefly summarized by Professor Ruzek as follows:

"Sulfur, and sulfur and manure, composted with rock phosphate and soil increased the amount of available phosphorus. These composts showed a gradual increase during the first twelve weeks of incubation, and then gradually decreased. Clover grown in pots in the greenhouse showed a more marked gain in yield than indicated by analyses. When lime was added to these mixtures it retarded the availability of the rock phosphate."

Value of sulfur and sulfate alternated with ground limestone in humid climates. Trials are under way including the sulfur, lime, and manure combinations, especially on four humid red hill soils (Table XIX). Sulfur has given slightly greater increases than phosphorus on these soils, and lime has given moderate to good results. In the Multnomah experiment just cited, lime, manure, and sulfur have given good results on a soil containing good amounts of phosphorus but of rather low availability, due to high iron content. Sulfur alone has depressed growth of vetch in one instance. Sulfur alone applied to Willamette silty clay loam at Corvallis has increased acidity somewhat. In the Multnomah county experiment above cited, combined application of sulfur and manure gave the highest yields.

The yield of spring wheat on Carlton silty clay loam in Benton county, 1922, for plots involving sulfur is reported in Table XIX.

TABLE XIX-a. USE OF SULFUR IN ALTERNATION WITH LIME FOR HUMID SOILS—CARLTON SILTY CLAY LOAM, BENTON COUNTY

Treatment	No lime	Lime, 2 tons an acre
Ave. all checks. Wheat, bushels per acre	12.6	12.5
Sulfur 150 pounds an acre	31.7	20.5
Sulfur 150 pounds an acre and manure 10 tons + rock phosphate 1000 pounds an acre	19.5	15.0
10 tons manure and treble superphosphate 110 pounds an acre	14.5	12.7

A dry season caused lower elevations to yield more and interfered.

In Marion county in a fertilizer experiment on Olympic clay loam that had been limed and manured the yields were as follows:

TABLE XIX-b. USE OF SULFUR ALTERNATED WITH LIME OLYMPIC SILTY CLAY LOAM, MARION COUNTY

	Corn yield in tons
Lime 2 tons and manure 10 tons an acre	7.20
Lime 2 tons and manure + sulfur 100 pounds an acre	9.40
Lime 2 tons and manure + sulfur + rock phosphate 600 pounds an acre	11.00
Lime 2 tons and manure + rock phosphate	6.28
Lime 2 tons and manure + treble superphosphate 100 pounds	8.00
Lime 2 tons and manure + acid phosphate 250 pounds	8.86

Here the sulfur and rock phosphate on limed, manured land gave the maximum yield. This experiment is of too short duration to warrant any definite conclusion as to value of sulfur on these soils.

EFFECT OF SULFUR ON ACIDITY OF HUMID SOILS

Heavy and repeated applications of sulfur have been made in the Oregon experiments to learn the ultimate effect of using sulfur upon soils. Samples of the oldest (1915) series of plots on antelope clay adobe were collected (1922) and submitted to the Truog acidity test. Only slightest acidity was found in the case of the one plot receiving 600 pounds an acre of sulfur at each application. These samples were also submitted to the department of Bacteriology for hydrogen-ion tests with results as follows:

TABLE XX. EFFECT OF SULFUR ON REACTION

	Can	Plot. No.	Treatment	Amount 1915-'17-'20	Ph. *
1915	1	5	Check		7.2
1915	2	6 E	Sulfur	100 pounds an acre	7.0
1915	3	7 W	Sulfur	300	7.0
1915	4	7 E	Sulfur	300 reapplied	7.0
Jan. 1916	5	2	Sulfur	600	6.8

* Ph. 7.0 represents neutrality, lower values acidity.

Samples were collected in November, 1922 from certain of the fertility plots on Willamette silty clay loam started at Corvallis in 1914 and retreated in 1917 and 1920 at rates given in Table XXI. Tests were made by the department of Bacteriology with results as follows:

TABLE XXI. EFFECT OF VARIOUS FERTILIZERS ON H-ION CONCENTRATION

Plot	Treatment	Sample A	Sample B
13	Check	5.7	5.7
14	Nitrate 100 pounds	5.8	5.8
15	Potash sulfate 160 pounds	5.7	5.8
16	Superphosphate 320 pounds	5.6	5.6
17	Check	6.0	5.8
18	3000 hydrated lime	6.8	6.4
19	320 pounds sulfur	5.4	5.3
20	Manure 12 tons	6.3	6.2
21	Check	5.8	6.0
22	Potash, Nitrogen and Phosphate	5.8	6.0

The figures represent the Ph. values. Ph. 7.0 represents neutrality, lower values acidity.

Professor W. V. Halversen, who made these tests, makes the following observation:

"There are three very interesting things brought out by these tests; namely, (1) the neutralizing value of both lime and manure, (2) the acidity produced through the oxidation of sulfur, and (3) the fact that superphosphate has had very little effect on the reaction of the soil."

Some humid soils which are deficient in sulfur and respond to applications may not require repeated treatments, or the treatments may be lighter after the initial application. Continued use of sulfur on such humid soils may make more necessary occasional liming, alternated with sulfur applications.

EFFECT OF SULFUR ON NITRIFICATION

The dark green color of sulfured alfalfa, the increased nodule formation and higher protein content in irrigated sections all indicate that there is an important relation between sulfur and nitrification. This may be very different in an arid soil of alkaline reaction from what exists in a humid soil of moderate acidity. Use of gypsum on clover in Western Oregon is an established practice and has been followed for a generation. Gypsum is used on the Experiment Station farm as a definite aid in establishing a new seeding of clover. To study the effect of such treatments the writer ran some pot tests with Dayton silty clay loam in March, 1921. The soil was brought in from the field at the close of the rainy season in quantity sufficient to fill 8 one-gallon earthenware jars. Four jars were planted to red clover and four were kept as a fallow series. One pot of each series was treated with sulfur, a second pair with gypsum, and a third with sulfur and lime. The remaining pair were used as controls. Jars were kept at about the optimum moisture content under greenhouse conditions and sampled and tested for nitrate every ten days. At the beginning of the trial scarcely a trace of nitrate could be found in the soil used. Nitrates began to form during the first ten days, and differences increased until the harvest time in June, when results were as reported in the following table:

Fig. 14. Plots used in alkali reclamation experiments.

DAYTON SILTY CLAY LOAM, SPRING 1921

	Treatment	Mgs. NO_3 per 100 gms. soil	Yield of clover in grams per pot	Yield of clover in grams per pot
Clover		Fallow pots	Clover pots	
1	None	57.1	21.0	11.51
2	100 pounds an acre sulfur	33.6	12.4	12.94
3	100 pounds sulfur + 3000 pounds lime	49.8	25.1	12.38
4	200 pounds gypsum	43.0	9.2	8.95

This trial indicated that with this acid soil sulfur alone tended to depress nitrification, while its use in combination with lime stimulated nitrification.

This led to a more careful study of the problem by the department of Bacteriology with a humid soil known to respond to sulfur, with results described by Professor W. V. Halversen as follows:

"It is generally conceded that alfalfa and clover are heavy nitrate feeders. At the same time it will be readily surmised that nitrate production would be inhibited through the accumulation of inorganic acids. These lines of reasoning would lead us to conclude that the phenomenal increase in the yield of alfalfa when sulfur is applied to some soil types is entirely due to the supplying of a limiting plant food element.

"To check carefully on the relation of sulfur oxidation to nitrate production, some tests and observations were made on a sample of Carlton clay loam. A large sample was procured from the field, divided into seven portions, and treated as shown in the following table. Each of these portions was again divided and placed in two gallon jars in the greenhouse, one portion being kept fallow and the other planted to clover.

Fig. 15. Sweet clover on partly reclaimed alkali land.

"The following table shows an intimate relationship to exist between the soil treatment, nitrifying power, and crop yields.

No.	Treatment	Mgs. N.as NO_3 per 100 gms. soil Fallow (4 det.)	Yield of clover in grams per pot	H-ion concention
1	Check	4.50	13.9	5.8
2	100 pounds sulfur	3.95	16.3	5.7
3	500 pounds sulfur	3.92	12.9	5.5
4	200 pounds gypsum	4.12	15.7	5.8
5	100 pounds sulfur + 2000 pounds lime	5.83	16.6	6.0
6	500 pounds sulfur + 200 pounds lime	5.05	15.5	5.7
7	2000 pounds lime	5.29	15.0	6.0

"Determinations have been made on the amount of nitrate accumulating in the soil and also on the power of the bacteria in the soil to produce nitrates from ammonia. Though this work is still in progress certain things seem apparent.

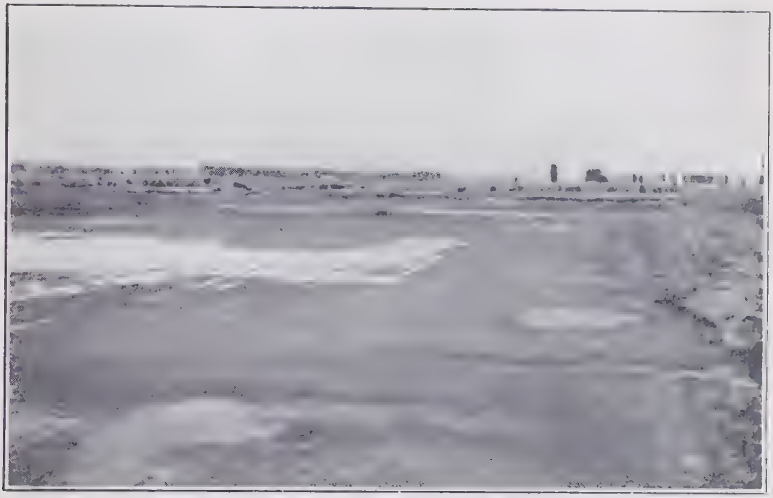

Fig. 16. Greasewood land, Vale, Oregon. Rye failed after drainage and with no chemical treatment.

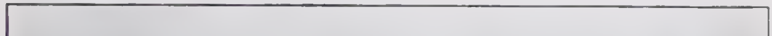

Fig. 17. Greasewood land, Vale, Oregon. Received sulfur and manure and yielded one ton of rye hay an acre after drainage and flushing.

"1. That the application of sulfur alone lowers the nitrate producing power, whereas 100 pounds of sulfur applied with one ton of lime stimulates the nitrate producing power of Carlton clay loam.

"2. Lime and sulfur together gave the largest yield of clover under greenhouse conditions. The second largest yield of clover came from 100 pounds of sulfur alone per acre.

"3. The oxidation of large quantities of sulfur materially lowers the yield of clover, also the nitrate-producing power and increases the acidity of this soil type.

"This problem is being carried out in the Bacteriology department in cooperation with the Soils department."

EFFECT OF SULFUR ON WATER REQUIREMENT

Sulfur treatments included in tank and pot water-requirement studies indicate that sulfur is an especially critical element, although only a little seems to be required. Results of one such trial are given as an illustration.

WATER REQUIREMENT OF OATS GROWN ON DESCHUTES MEDIUM SANDY LOAM SOIL

	Yield	Water requirement per lb. dry matter
Untreated	16.2 gm.	2125 pounds
Sulfur 100 pounds an acre	57.9 gm.	594 pounds

VARIOUS EFFECTS OF SULFUR IN AGRICULTURE

Sulfur controls many plant diseases and parasites. Potato scab is held to be decreased by sulfur as a result of increased soil acidity, and activated sulfur is regarded by the New Jersey Station as more prompt and effective for this purpose than ordinary sulfur. The red spider pest has been effectively controlled by dusting with sulfur on Oregon soil plots. Eel worm and numerous other pests are controlled with sulfur. Sulfur is used in numerous ways and applied in stables may prevent spread of some diseases in manure.

RECOMMENDATIONS AS TO USE OF SULFUR ON OREGON SOILS

Sulfur is essential to crops, especially legume crops and those of the cabbage family, many of which require more sulfur than phosphorus.

Sulfur appears to be insufficient in soil to insure good crops, especially in the arid and semi-arid sections or the old leached, basaltic hill lands in the more humid sections of Oregon.

Application of eighty to one hundred pounds of sulfur an acre every three or four years should give a ton or more increase in yield of legume hay on most of the alfalfa lands of the state. Subsequent applications may be lighter, especially on humid soils. Apply early and harrow in at the time meadows are renovated. Fall application is best under dry farming or where sulfur is slow acting, for this material must oxidize to sulfate form to become available.

The method of applying sulfur may be the same as with land-plaster. Mixing damp sand with equal parts of sulfur will lessen drifting and render sulfur less obnoxious to broadcast by hand.

Ground commercial sulfur should best overcome any sulfur deficiency in soils over a period of years.

Where sulfur is deficient in humid sections of Oregon ground commercial sulfur judiciously employed will often be cheaper treatment than gypsum for legumes.

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Station Bulletin 200 December, 1923

Oregon Agricultural College

Experiment Station

A Study of Growth in Summer Shoots of the Apple with Special Consideration of the Role of Carbohydrates and Nitrogen

By

E. M. Harvey

CORVALLIS, OREGON

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A Study of Growth in Summer Shoots of the Apple with Special Consideration of the Role of Carbohydrates and Nitrogen

By

E. M. Harvey

INTRODUCTION

The present report of investigation deals with one phase of a general problem being conducted by the Horticultural department; namely, "The nutritional changes in fruit trees as related to behavior and cultural practices." A previous bulletin of this Station[4] reported the results for two other phases of the same general problem. The point of view of the previous work is maintained in the present; the chief departure from the previous studies is in the material used. In the former, attention was directed to the spurs, and, specifically to spurs as regards the processes of fruit bud formation and setting of fruit, while in the present investigation, attention has been transferred temporarily to the terminal growing shoot.

The aim of the present study was not, primarily, the determination of chemical changes accompanying growth, nor the making of growth curves, but rather, to seek a basis for a better explanation of some of the wide differences in growth response to pruning and other orchard practices, recorded in horticultural literature. It was also hoped that some light might be thrown upon one or more subsidiary questions, such as the following: (1) At what stage of development do apple shoots cease to receive contributions of elaborated food materials from older portions of the tree? (2) When does the direction of the general flow of elaborated food reverse; that is to say, when does the shoot begin to contribute to the older portions of the tree? (3) What proportion of the food manufactured by the growing shoot is used for its own extension and development during the first season?

A chemical method was employed in the attack on the above questions, but in order that the meaning of any observed chemical changes in the shoots might be as manifest as possible, the normal processes of growth were frequently interfered with by means of ringing and defoliation. To judge the effectiveness of ringing and defoliation as experimental methods for disturbing the normal activities of the shoot, or for partial isolation of the shoot from the rest of the tree, one needs to know more about the actual processes occurring within the shoot than the available information seems to permit. Only lately there ceased to be a general concensus of opinion on so apparently simple a matter as the path of translocation in the shoot. But for an attack on the growth problem in hand, there was great need for a suitable experimental means, and lacking much conclusive information, it appeared desirable to assume, as a working basis only, the truth of Curtis' [1-2] important conclusion regarding the path of translocation, which is this: that elaborated food materials travel both "down" and "up," exclusively in the phloem. This assumption suggests that as means for physiologically isolating for study separate organs of the tree there may be greater possibilities for ringing and defoliation than were formerly considered. Such studies, if they be possible, should hold several experimental advantages over those made on the tree as a whole. Certain advantages might be expected to accrue from the following facts; namely, (1) that organs of a fruit tree show considerable "individuality" in their response to natural or experimental conditions which may be imposed on the tree as a whole; (2) that different organs of the tree have different functions, and may perform them at different times, hence the opportunity is suggested for study of the relation of internal conditions to specific function in the organ; and (3) that the employment of the individual organ allows all experimental treatments and controls to be equally represented on every tree, thereby practically off-setting individual tree differences which are ever present and, too often, the dominating obstacle of the field-plot method.

Supplemental to the preceding paragraphs, it may be stated briefly, that the studies reported in this bulletin are on the growth responses of apple shoots as affected by various forms of ringing and defoliation, observable through measurements and chemical analysis. The field and laboratory work was carried on during the period 1920-23 inclusively.

GENERAL METHODS

A. GENERAL PLAN OF FIELD WORK

The trees furnishing the material for these shoot studies were seven to nine years old and selected always with the view of securing uniformity of size and vigor. The field-plot method was not used, but rather the attempt was made to off-set individual tree differences through the adoption of an unchanging policy of maintaining on each tree an equal distribution of shoots as regards numbers, treatments, and position. This is, however, the same method employed in the apple spur studies reported in Station Bulletin 176.[4]

The varieties involved in these experiments were chiefly Grimes and Spitzenburgs, with occasional use of Arkansas Black, Rome, and Gano.

The details of arrangement of experiments, the varieties and number of shoots involved, and the special treatments employed will be described in connection with the report of results of each series of experiments.

B. METHOD OF RINGING AND DEFOLIATION

The ringing operation was usually done at a point on the shoot 6 to 8 centimeters "above" the juncture of the new growth with that of the preceding season. A basal portion was thus left on each shoot below the ring, and in the presentation of results a distinction frequently will be drawn between this basal portion and that above the ring (see Fig. 11). The ringing itself consisted of the removal of a complete ring of bark which was about 5 to 8 millimeters in width, entirely through the bark tissue. These were made with caution in order not to injure the xylem, and the wound surface was treated immediately with rather thick liquid grafting wax to prevent drying out. In one group of ringing experiments, Series E, the rings were made just below the new growth in that of the preceding season (see Fig. 25).

The defoliation treatments were usually similar to the ringing, in that the regions of the shoot involved were the same, that is to say, the leaves were removed from a point 6 to 8 centimeters above the base of the shoot, leaving a basal portion not directly disturbed. Where other types of defoliation were employed, they will be described when the responses from them are reported.

Where ringing and defoliation are combined the ring was always placed 6 to 8 centimeters above the base of the shoot, and all leaves removed above it.

C. DETERMINATION OF GROWTH

The term "growth" as used throughout this report refers to increase in length only. This increase was determined by the simple process of measuring, to the nearest half centimeter, at stated intervals, the length of the shoot from base to tip. The intervals between measurements varied through the experiments from one to nearly five weeks.

D. COLLECTION AND PRESERVATION OF MATERIAL

Shoots collected for chemical analysis were always taken from the trees early in the morning (5:30 to 7:30 a.m.) in order to have as uniform a chemical base line in the tissue, throughout the season, as possible. After cutting, the shoots were placed immediately into large botanical collection cans, and before 8 a.m. were brought to the laboratory. Requisite division was made of these lots, whether into leaf and stem or "top" stem and "basal" stem samples, as quickly as possible, so that the fresh weight determination of each sample could be made. No more collecting was done any morning than could be carried through the first critical stage (i.e. to placement in the oven) within three hours after the arrival of the shoots in the laboratory. The procedure through which the shoots were taken during this early stage was as follows: After division of the lots into the various samples, they were placed in large evaporating dishes and the fresh weights determined. Then they were chopped to small pieces and lightly covered with 94 percent redistilled alcohol and transferred to the vacuum desiccator for about four hours at 75° to 80° C. The temperature of the oven was increased after this period to 95° C. and held so until the samples were completely dry.

E. METHODS OF CHEMICAL ANALYSIS

The general procedures in the chemical analysis reported in this work were essentially the same as those employed in the spur studies of Bulletin 176 of this Station, and as described on pages 18 to 20 of that work. It was necessary, however, to make a few changes in those methods as detailed below.

1. **Extraction.** All samples, except the leaf samples of Series B, were separated into hot-alcohol soluble and insoluble fractions as described in Bulletin 176, the preparation for extraction, etc., being the same, except for the slight modification previous to grinding. The tissue here was ready for immediate grinding on account of its not having been preserved in alcohol as formerly.

2. **Dry weights.** Dry weight of the entire sample was determined on removing the tissue from the oven. The dry weight of the insoluble fraction was determined after extraction. With this and the total dry weight value, the dry weight of the soluble fraction was also obtained.

3. **Nitrogen.** Total nitrogen determinations were made separately on the two fractions by the Kjeldahl method as modified by Gunning-Arnold. No separation of soluble and insoluble nitrogen was made for the leaf samples of Series B for the reason mentioned in (1) above.

4. **Carbohydrates.** (a) *Reducing and total sugars.* These were determined by the official method used in the previous spur studies, except that this official procedure was departed from with respect to the conditions surrounding the copper reduction by the sugar solutions. Instead of the regular four-minute heating, plus two-minute boiling periods, a modification of these conditions to a half-hour period at 80° C. was adopted for all sugar determinations in this report. This modification is the one suggested by Quisumbing and Thomas[8] whose procedure was followed in most details. Calculations of sugar equivalent to the copper reduced were made by means of the formulas published by these authors, and the entire method checked against standard sugar samples from the United States Bureau of Standards. And as a thing of great working convenience, it should be mentioned that a reference table was prepared, to show the amounts of invert sugar and glucose equivalent to copper values from 10 to 180 milligrams, proceeding by two-milligram intervals.

The modification above was adopted in consideration of what were judged to be real points of superiority over the official reducing procedure, as follows: (1) uniformity of conditions; (2) much more ease of manipulation; and (3) a 60 percent increase in speed.*

(b) *Phloridzin.* The method employed in the determination of Phloridzin was that suggested by Harvey.[5] A 50 c.c. portion of the soluble fraction, comparable with the portion used for reducing and total sugars, was transferred to a 200 c.c. Florence flask. To this were added 26 c.c. of water and 4 c.c. of concentrated hydrochloric acid (sp. gr. 1.18). The flask was then connected with an air condenser and placed upon a large Hoskin's hot-plate and the temperature adjusted so that the solution would simmer with an occasional ebullition, for 2½ hours. The solution was then cooled, transferred to a 100 c.c. volumetric flask, neutralized, and made up to volume. The reduction and titration procedures were the same as for the sugars. The method for calculating phloridzin is as follows: From the total potassium permanganate (n/20 solution) titration obtained above, subtract the value of the titration of total sugars; the difference, in cubic centimeters of permanganate solution, translated to its copper, and then to its glucose equivalent, is assumed to come from phloridzin (cf. Harvey[5]). Conversion of this glucose value to anhydrous phloridzin is made through multiplying by the factor 2.42.

(c) *Pentosans.* Pentosans were determined by one of the two following methods:

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* Reductions were carried out in 400 c.c. beakers, covered and immersed in an eight-hole steam-heated water bath, provided with a strong stirring device. Temperature was constant at 80° C. within a range of one degree. With this equipment, sixteen reductions per hour were made with considerably more ease and uniformity than the maximum ten per hour by the official procedure.

(1) Phloroglucin method. The procedure recommended by the Association of Official Agricultural Chemists was followed in detail.

Pentosan figures reported for the stem samples of Series B were obtained by this method:

(2) Modified Spoehr[10] method. The solution obtained by the regular 2½-hour acid hydrolysis (in the regular determination of total polysaccharides) was submitted to a fermentation by baker's yeast. The non-fermentable pentose sugars were determined as glucose and the values translated to pentosans by use of the factor 0.85.

The leaf samples of Series B were analyzed by this method.

(d) *Starch.* The taka-diastase method was employed, practically as recommended by Davis and Daish.[8] A serious objection to this method would seem to arise from the fact that the commercial taka-diastase powders carry an extremely large amount of reducing substances which give an inconveniently and dangerously large blank determination.

(e) *Total polysaccharides.*[*] These were determined by the same method and procedure as described in Bulletin 176.

RESULTS AND DISCUSSION

1. PRELIMINARY EXPERIMENTS

The first attack on the growth problem in hand was made in the summer of 1920. The experiment was a rather small one and of a preliminary nature. The methods of ringing and defoliation were tried with the intention of estimating the general effectiveness of these practices as aids in the study of shoot growth. The plan was to ring and defoliate shoots in various ways, and from observation of the growth responses to judge the merits of these methods for a later chemical study. The growth responses obtained agreed in general with those reported by

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[*] It may be of interest to have presented below the average figures which were obtained from a large composite sample of apple shoots (stems only). The data show the inter-relation of the substances considered in this bulletin better than a summary of analyses of individual experimental samples. More attention is given here, however, to the various constituents of the hot-alcohol insoluble fraction than in the experimental work reported later. In outline this composite sample gave the following results:

135.0 grams fresh tissue *(on drying became)*

56.5 grams *(hence water = 58.2%)*

(on extraction was separated into)

Soluble matter = 22.2% *(on partial analysis gave)*

Insoluble matter = 77.8% *(on partial analysis gave)*

Reducing sugars	Sucrose	Phloridzin	Soluble nitrogen	Starch	Mannans and other hexosans	Pentosans (by Spoehr method)	Pentosans (by phloroglucin method)	Total hydrolyzable polysaccharides	Insoluble nitrogen
0.92%	1.20%	3.26%	0.093%	2.6%	4.2%	11.7%	19.0%	20.4%	0.481%

Curtis,[1] but the reaction of these first-hand findings on the writer was sufficiently strong that they formed the background, and became the guide for all the later experimental studies. A brief account of the arrangement of the preliminary experiment and results will be given below.

The varieties used were: Gano, Spitzenburg, and Rome. The trees set aside for the work were very heavily headed back in the preceding March in order to produce abundant and vigorous shoots. The ringing and defoliation were performed on June 20, at a time when the growth of the shoots was still rapid. The shoots were tagged and their lengths carefully determined, and divided into four lots for the following treatments: (1) checks, entirely untreated; (2) ringed only (ring 6 to 8 cm. above base); (3) defoliated only (all leaves removed above point 6 to 8 cm. from base); and (4) ringed and defoliated (treatments (2) and (3) combined). There were three trees of each variety and each treatment was represented by seven shoots on every tree. These shoots were not disturbed again until July 21, when their length was redetermined. The growth responses to each treatment are summarized in Table I. An examination of this table will show that the Gano and Spitzenburg shoots, which were ringed only, gave greatest growth of all treatments, but the defoliated Rome shoots, although they did not grow more than checks, grew relatively more than the ringed shoots of the preceding varieties. In other words, in the Rome shoots the situation as regards the relative growth after ringing and defoliation is the reverse of that in the Gano and Spitzenburg. Ringing plus defoliation practically stopped growth immediately in all three varieties.

TABLE I. EFFECTS OF RINGING AND DEFOLIATION ON GROWTH OF SHOOTS

Preliminary Experiments

Variety	Treatment	Length June 20	Length July 21	Increase in length after treatment	Percentage of increase
		cm.	*cm.*	*cm.*	%
Gano	Checks	41.5	61.0	19.5	45.7
	Ringed	42.0	63.2	21.2	50.5
	Defoliated	38.0	52.0	14.0	36.7
	Ringed plus defoliated	42.0	44.0	2.0	4.8
Spitzenburg	Checks	42.3	71.5	29.2	69.0
	Ringed	44.2	78.3	34.1	77.2
	Defoliated	41.5	60.8	19.3	46.5
	Ringed plus defoliated	52.3	55.2	2.9	5.5
Rome	Check	43.1	60.3	17.2	39.9
	Ringed	50.2	60.8	10.6	21.1
	Defoliated	44.4	59.2	14.8	33.3
	Ringed plus defoliated	46.4	48.5	2.1	4.5

The facts that ringing accelerated growth in Gano and Spitzenburg and retarded it in Rome shoots, together with the correspondingly opposite effects of defoliation, were found difficult to bring into harmony with Curtis'[1] explanation for apparently similar growth responses to the same treatments. He explained the retardation of growth by ringing, on the basis that the removal of a ring of phloem cut off the supply of elaborated food from "below," so creating a food deficit, and hence a slowing down of growth activities. Retardation from defoliation was explained also on the grounds of a food deficiency. But this investigator noted that ringing sometimes accelerates growth, a fact which he explains by assuming that while the leaves were previously manufacturing enough food for good growth, the optimum amount could not be accumulated on account of the normal downward flow through the phloem. Ringing then, by checking this flow away from the shoot, increased the food content, and accelerated growth. This explanation for the reversed effects of ringing, while being generally very acceptable to the writer, and apparently applicable to the results recorded for Gano and Spitzenburg, did not seem to apply with equal ease to the response of the Rome shoots in which ringing retarded growth. Growth had slowed considerably in the Rome shoots by the time the experiment was begun. This situation was indicated both by the recorded data and the general field appearance of the shoots. If it be granted that growth had slowed more in this variety than in either of the others, the checking of growth by ringing cannot well be attributed to the lack of food. Certainly not to lack of carbohydrate material, since ringing at that stage of shoot development should increase the carbohydrate content. The wide differences of growth response which may be expected to follow ringing or defoliation lead one to conclude that either of these methods will cause a shoot to grow faster or slower according to its stage of development when the operation is performed. In consideration of this possibility, the writer endeavored to make a tentative analysis of the general processes in the shoot as regards the manufacture and movement of food materials in relation to its growth and stage development. The first working assumptions induced were based on two other assumptions: the first, that elaborated food materials of the shoot move principally through the phloem (Curtis[1-2]); and the second, the carbohydrate-nitrogen theory of Kraus and Kraybill.[6] The assumptions based on the above became the guide to much of the experimentation to be reported later in this paper, and they are as follows: (a) If the carbohydrate supply of the shoot is somewhat limited, *ringing* will retard growth very slightly, or may in fact accelerate it, but *defoliation* will greatly retard growth. (b) If carbohydrates are abundant in the shoot, and the nitrogen supply somewhat limited, *ringing* will retard growth, but *defoliation* will retard it very slightly, or may greatly accelerate it.

It must be pointed out immediately that the above assumptions were intended to apply only to shoots which have reached a later stage of development, when, if there is any general movement of carbohydrates, it is "downward" or out of the shoot. Early stages of development would require considerable modification of the above assumptions, as will be detailed farther on. But were a tentative application made of the above to the shoot performances recorded in Table I, it would be necessary to place the shoots of Gano and Spitzenburg in group (a) and Rome in group (b). Unfortunately, however, there were no chemical analyses for this experiment, so that the internal conditions of the shoots could not be checked.

2. SERIES C

Series C is a study of growth in the normal untreated apple shoot. The data accumulated from it have a bearing on the relation of the distribution of the large groups of chemical constituents, in different regions of the shoot, to its seasonal growth curve. Since this study deals only with the untreated shoot, it seems desirable to present the results before considering the more strictly experimental series which deal with the behavior of shoots after ringing and defoliation operations.

With reference to the distribution of certain substances in the normal growing shoot, a number of questions arise apropos of the general problem in hand, as for example: (1) What chemical differences are to be noted between the region of the growing point and the base of the shoot? (2) Are those substances, commonly associated with good growing conditions (e.g., water, soluble solids, and nitrogen, etc.) more abundant in the tip region and do they diminish there less rapidly through the season, than in the base? In other words, is the complex of conditions favoring growth more constant at the tip through the growing season than is indicated by the usual seasonal curves obtained from analyses of the entire summer shoot? (3) If at the tip of the shoot, this complex of conditions favoring growth, including a relatively low carbohydrate-nitrogen ratio, does remain constant through the growth season, or at least much less changeable than in other regions of the shoot, would it not indicate a closer correlation between growth in length and a definite internal condition than previous seasonal analyses of summer shoots have shown?

With these questions in mind, fifteen trees each of the varieties, Grimes and Arkansas Black were selected to furnish material for a study of normal shoot growths. Fifty shoots were selected and tagged on each of the above thirty trees. All these shoots were measured first on June 2, at which time they averaged 4.0 cm. and 10 cm. for the Arkansas Black and Grimes respectively. In both varieties, terminal growth had begun one or probably two weeks previous to this measurement; unfortunately, therefore, the shape of the grown curve in its earliest portion cannot be determined from the data obtained. The shoots remaining on the tree after procuring each chemical sample were remeasured June 9 and 23, July 4, August 2, and September 11. On each of the measurement dates, as indicated, shoots were taken for chemical study. The sizes of the chemical samples at each collection date were as follows: for the first three collections they consisted of ten shoots; for the fourth collection, eight shoots; and for the fifth and sixth collections, six shoots from each tree. Thus the total number of shoots collected from each variety on each date ranged from 150 to 90 through the season.

These collected shoots were immediately stripped of leaves and divided into three portions: (1) the "tips," which consisted of the upper 3 to 4 cm.; (2) the "base," the lower 6 to 8 cm.; and (3) the "middle," which was that portion of the shoot remaining after the "tip" and "base" samples had been taken, consequently the individual pieces making up the sample varied greatly in length. The first collection alone deviated from the above in method of division of samples, seeing that the shoots were so small that there was no material left for "middle" sample; and in the Arkansas Black, even the "base" samples were rather small and made scarcely a representative collection.

Growth. The growth curves for the summer shoots, derived from the data obtained, agree closely with the growth curves for the shoots of other woody plants, including the apple, published by previous workers. The present curves are shown in Fig. 1. The fact that the shoots had been growing for about two weeks before the first measurements were made probably accounts for the failure to show the slow initial rate of growth that is so striking a characteristic of the seasonal growth curves published by Reed[9] and Ludwig.[7] It was the original intention to observe this early stage of the growth in the present work, but the shoots passed through this critical stage too quickly to be observed that season. There is evidence from the data, however, that the Arkansas Black shoots had not reached the maximum growth rate until the second observation interval.

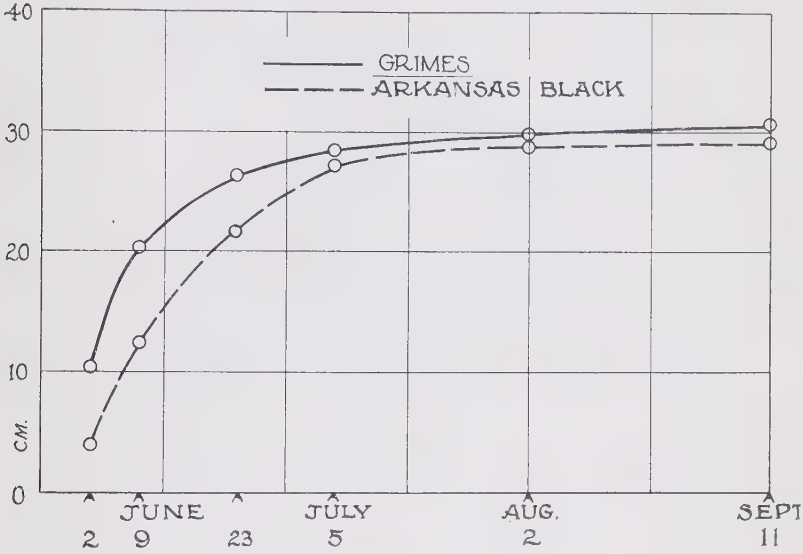

Fig. 1. Growth curves of apple shoots. Series C.

Chemical. A summary of the chemical analyses of the normal growing shoots is presented in Tables II and III. The Grimes and Arkansas Black shoots behave much alike, in so far as the chemical data show. A glance at the tables reveals the fact that there is considerable difference in chemical composition between the "tip," "middle," and "basal" regions of the shoot on any given date. It is equally easy to see that the composition of each of these regions of the shoot varies greatly throughout the season. Most changes of chemical composition, either along the shoot or throughout the season appear to be generally consistent and uniform. As regards the composition of different parts of the shoot in relation to the season, two generalizations may be made: (1) Those substances which normally decrease through the season are always most abundant in the "tip" portion of the shoot and least abundant in the base. (2) Conversely, those substances which tend to increase during the season are least abundant in the "tip" and most abundant in the "basal" portion. Substances belonging to the former group were: water, soluble solids, phloridzin, and soluble and insoluble nitrogen. Belonging to the second

TABLE II. SUMMARY OF CHEMICAL ANALYSES OF UNTREATED SHOOTS.

Grimes. Series C.

Date	Part of shoot analyzed	Water	Soluble solids	Insoluble solids	Reducing sugars	Sucrose	Total sugars	Polysaccharides	Total carbohydrates	Phloridzin	Soluble nitrogen	Insoluble nitrogen	Total nitrogen	C/N
June 2	Tip	74.0	44.1	55.9	0.42	0.35	0.77	10.16	10.9	11.20	—.23	0.15	0.38	28.8
	Middle	....	....	....	....	....	....	....	....	....	....	....	....	....
	Base	70.1	31.6	68.4	1.00	0.05	1.05	15.00	16.1	5.90	0.16	0.09	0.25	64.2
June 10	Tip	70.6	43.7	56.3	0.41	0.46	0.87	10.77	11.6	12.25	0.21	0.14	0.35	33.2
	Middle	69.3	30.7	69.3	0.97	0.10	1.02	14.14	15.2	5.57	0.15	0.09	0.24	64.8
	Base	64.0	24.4	75.6	1.10	0.04	1.14	16.86	18.0	3.36	0.12	0.06	0.18	99.4
June 24	Tip	67.7	41.3	58.7	1.02	0.75	1.77	11.95	13.7	9.95	0.19	0.10	0.29	46.8
	Middle	62.7	26.2	73.8	1.05	0.02	1.07	18.00	19.1	5.18	0.10	0.06	0.16	125.5
	Base	57.7	20.0	80.0	1.14	0.03	1.17	18.60	19.8	3.94	0.06	0.04	0.10	190.0
July 5	Tip	63.4	34.8	65.2	0.99	0.14	1.12	15.15	16.3	8.13	0.14	0.08	0.22	73.2
	Middle	60.0	23.5	76.5	1.00	0.03	1.03	17.90	18.9	4.46	0.08	0.05	0.13	146.5
	Base	56.3	18.3	81.7	1.12	0.00	1.12	16.45	17.6	3.26	0.06	0.04	0.10	188.8
Aug. 2	Tip	55.2	26.1	73.9	0.80	0.14	0.94	17.24	18.2	5.93	0.11	0.06	0.17	111.0
	Middle	52.9	19.3	80.7	0.94	0.02	0.96	18.55	19.5	3.23	0.06	0.04	0.10	199.0
	Base	50.2	15.9	84.1	0.92	0.00	0.92	19.30	2.02	2.07	0.04	0.03	0.07	266.0
Sept. 13	Tip	50.6	22.6	77.4	0.87	0.00	0.87	20.08	21.0	5.40	0.12	0.07	0.19	109.0
	Middle	49.0	15.7	84.3	0.83	0.01	0.84	21.35	22.2	3.09	0.06	0.08	0.14	156.0
	Base	47.0	13.2	86.8	0.78	0.00	0.78	23.50	24.3	2.34	0.04	0.04	0.08	303.0

TABLE III. SUMMARY OF CHEMICAL ANALYSES OF UNTREATED SHOOTS.
Arkansas Black. Series C.

Date	Part of shoot analyzed	Water	Soluble solids	Insol-uble solids	Reduc-ing sugars	Sucrose	Total sugars	Poly-sacch-arides	Total carbo-hydrates	Phlo-rid-zin	Soluble nitro-gen	Insol-uble nitro-gen	Total nitro-gen	C/N
June 2	Tip	74.2	48.7	51.3	0.41	0.06	0.47	8.01	8.5	15.52	0.28	0.20	0.48	17.7
	Middle	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------	----------
	Base	71.5	39.5	60.5	0.72	0.12	0.64	13.03	13.7	6.00	0.23	0.12	0.35	39.1
June 10	Tip	72.2	47.5	52.5	0.48	0.09	0.57	8.74	9.3	15.68	0.27	0.18	0.45	20.7
	Middle	71.8	40.3	59.7	0.52	0.32	0.84	11.70	12.5	9.17	0.23	0.12	0.35	35.6
	Base	67.6	28.9	71.1	0.79	0.14	0.93	15.28	16.2	5.17	0.20	0.09	0.29	56.9
June 24	Tip	70.7	45.8	54.2	0.60	0.56	1.16	9.54	10.7	13.94	0.29	0.17	0.46	23.7
	Middle	67.0	31.4	68.6	0.68	0.15	0.83	14.93	15.8	6.15	0.22	0.09	0.31	52.2
	Base	61.3	23.4	76.6	0.84	0.09	0.93	18.08	19.0	3.71	0.13	0.06	0.19	101.2
July 5	Tip	68.4	39.9	60.1	0.50	0.37	0.87	12.06	12.9	9.05	0.22	0.12	0.34	36.4
	Middle	64.2	28.3	71.7	0.69	0.14	0.83	14.88	15.7	4.78	0.23	0.07	0.30	53.7
	Base	59.0	22.4	77.6	0.91	0.12	1.03	16.80	17.8	3.55	0.10	0.05	0.15	118.8
Aug. 2	Tip	56.7	26.6	73.4	0.28	0.23	0.51	19.25	19.8	5.75	0.16	0.07	0.23	87.4
	Middle	54.2	19.9	80.1	0.67	0.08	0.75	20.00	20.7	3.39	0.09	0.04	0.13	152.4
	Base	50.9	17.9	82.1	0.87	0.04	0.91	21.30	22.2	2.83	0.06	0.04	0.10	236.0
Sept. 13	Tip	50.1	22.4	77.6	0.68	0.11	0.79	22.06	22.9	5.35	0.11	0.08	0.19	122.8
	Middle	48.8	17.0	83.0	0.96	0.01	0.97	23.85	24.8	2.88	0.06	0.05	0.11	234.2
	Base	46.4	15.6	84.4	1.08	0.00	1.08	21.9	23.0	2.30	0.04	0.04	0.08	270.5

group were: insoluble solids, sugars, polysaccharides, and total carbohydrate, and the carbohydrate-nitrogen ratio. The relative behavior of these may be observed in Figs. 2 to 7, which give seasonal graphs of the principal substances mentioned above.

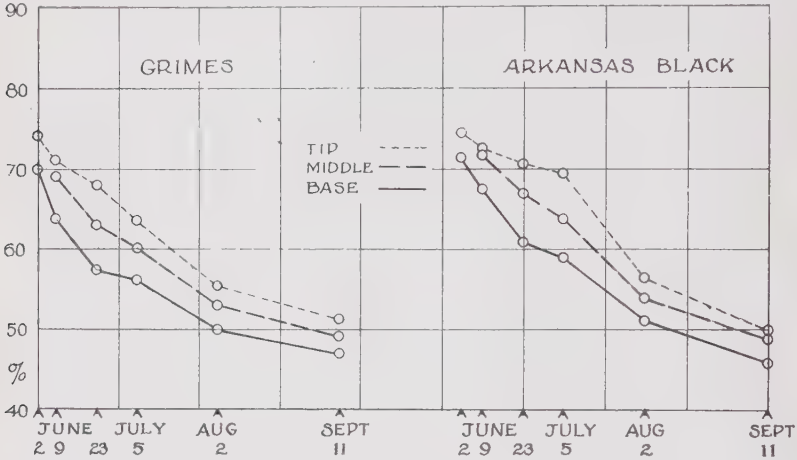

Fig. 2. Seasonal variation of water in apple shoots. Series C.

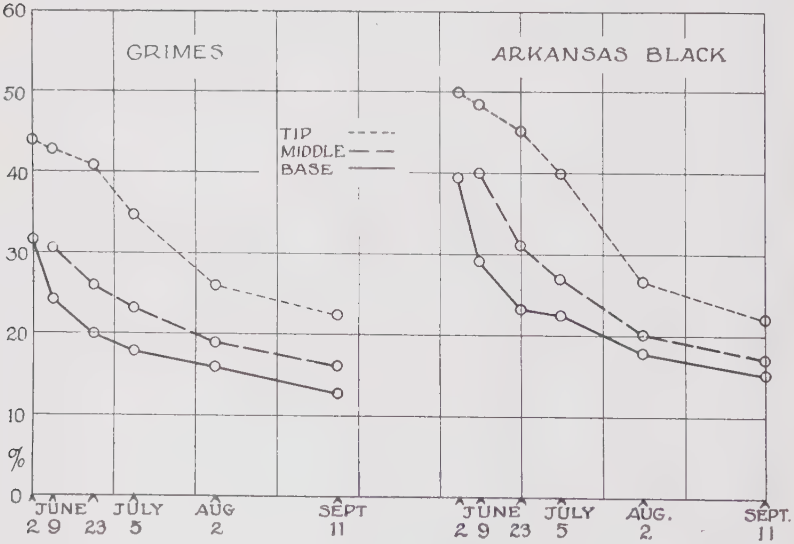

Fig. 3. Seasonal variation of soluble solids in apple shoots. Series C.

It was asked at the beginning of this section whether those substances which are most commonly associated with growth (namely, water, soluble solids, and nitrogen) are most abundant in the tip and diminish less rapidly there than in the base? In answer to this question it may be observed from the tables and figures presented, that the substances named above are more abundant and

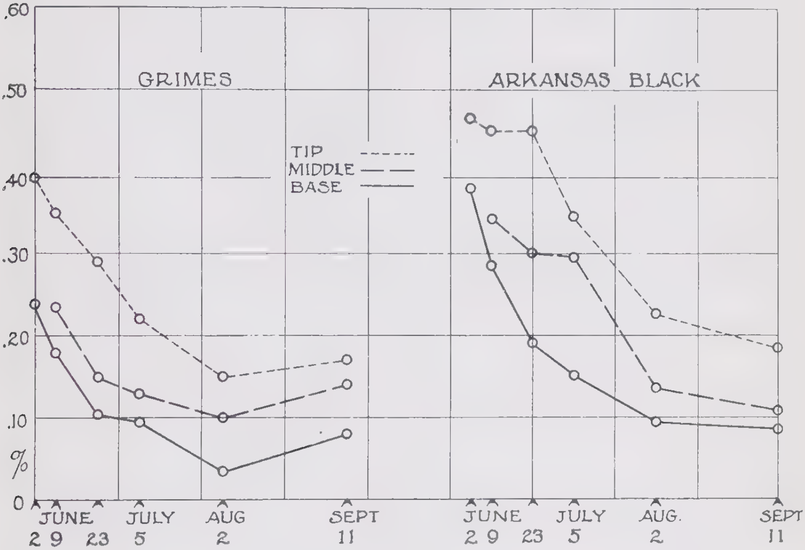

Fig. 4. Seasonal variation of total nitrogen in apple shoots. Series C.

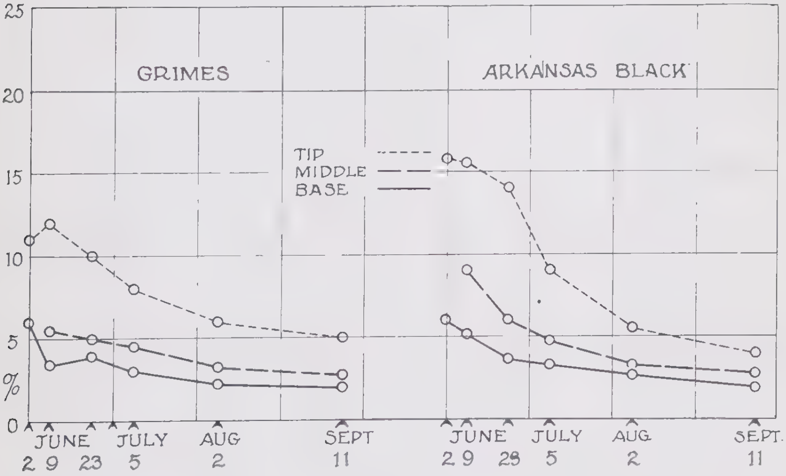

Fig. 5. Seasonal variation of phloridzin in apple shoots. Series C.

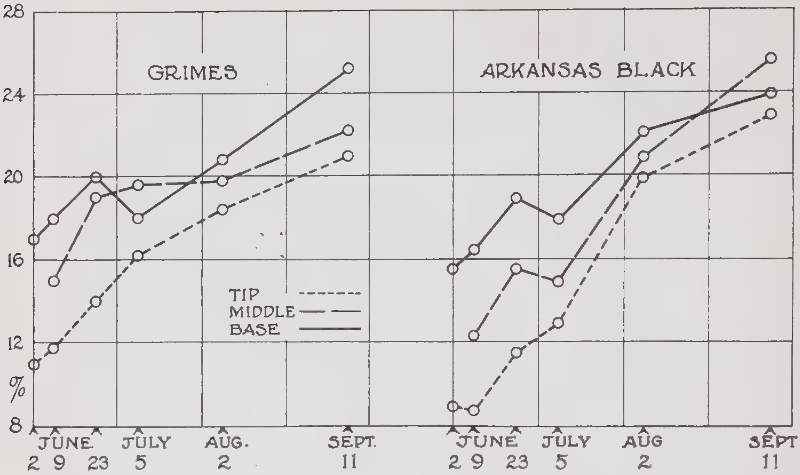

Fig. 6. Seasonal variation of total carbohydrates in apple shoots. Series C.

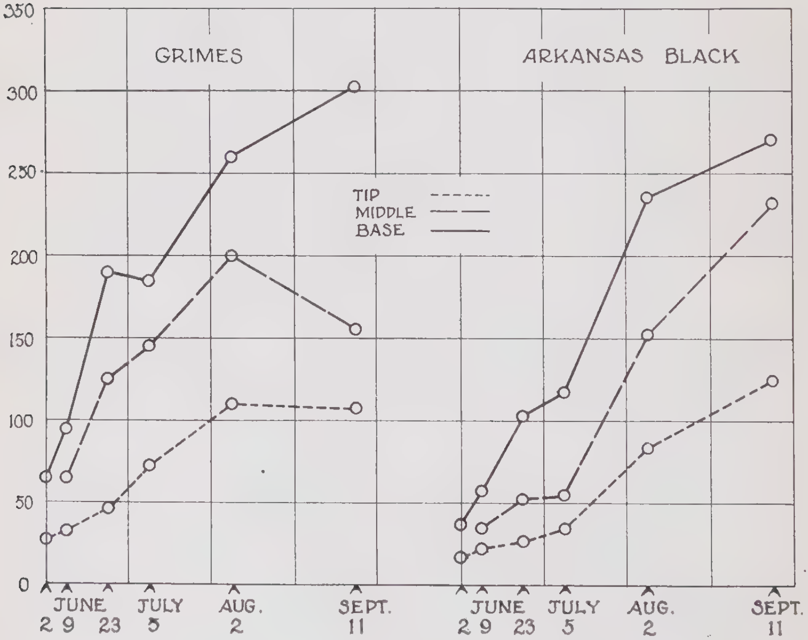

Fig. 7. Seasonal variation of carbohydrate-nitrogen ratios in apple shoots. Series C.

decrease less rapidly in the tip of the shoot. This indicates then, not only that the characteristic conditions favoring growth are better in the tip, but that such conditions are more constant there through the growing season than in any other general region of the shoot. Had analyses been made of the entire shoot instead of separate regions of it, the graphs plotted from the results would have indicated much more rapid falling away of growing conditions than is shown by the analysis of the tip alone, or is indicated by the observed growth rate. And it is not unreasonable to suppose that could chemical analyses be made of the ultimate growing point itself, the seasonal graphs for some of the substances named might follow much more closely the growth-rate curve than these of the "tip" samples show.

The chemical data presented here do not cover the period of slow growth rate at the beginning of the season. It is very possible, however, that chemical data for such period might indicate even better growth conditions then than two or three weeks later, when the growth rate is at its highest point. The reason for this supposition is, that the initial direction of the curves for the various substances in the present study do not indicate that they had been lower a week or two before, when undoubtedly a slower growth rate prevailed. It is more than likely that temperature and not chemical composition is commonly the limiting factor to growth very early in the season (cf. Ludwig[7]).

3. SERIES A

Series A is a study of growth response of rather short shoots, to complete defoliation only. The external observations of growth were supplemented with chemical analyses.

The shoots studied were 10 to 20 cm. in length at the time the experiment was begun. Two varieties were used, Grimes and Spitzenburg. It was the original intention in this series to secure shoots at an early stage of development, but the attempt was not very successful, particularly in the Grimes, which made a very poor growth but made it very early in the season. Defoliation was done on June 6, and the shoots were under observation until July 19, during which time were made three measurements of length and three collections of material for chemical examination. The measurement and collection dates were June 6, June 24, and July 19. The shoots were furnished by 12 trees of each variety, the check and defoliated shoots being equally distributed throughout these trees, both as regards number and position. Four check shoots were taken from each of the twelve trees for the first chemical sample, and the same number of check and defoliated shoots on the two following collections, so that each tree furnished a total of 20 shoots.

Growth. The growth data for Series A are given in Table IV. Noting the behavior of the Grimes checks, it is evident that this variety had practically ceased growth as early as the middle of June. Here there is a distinct acceleration of growth due to defoliation, an effect which does not at first sight seem in accordance with the original size of these shoots and the relatively early date of treatment. But that the actual condition in these shoots represented a late stage of development, where defoliation could be expected to accelerate growth, is evident by the slight growth made by check shoots after the

TABLE IV. EFFECTS OF DEFOLIATION ON GROWTH OF SHOOTS

Series A.

Variety	Treatment	Length June 6	Length June 23	Length July 19	Total increase after treatment	Percentage of increase
		cm.	*cm.*	*cm.*	*cm.*	%
Grimes	Checks	13.1	14.3	15.1	2.0	15.2
	Defoliated	13.8	15.4	18.3	3.8	27.5
Spitzenburg	Checks	18.6	23.1	36.0	18.4	99.4
	Defoliated	20.3	23.2	27.6	7.3	35.9

beginning of the experiment. The Spitzenburg shoots were caught at a relatively much earlier stage of development, since the checks increased practically 100 percent in length after the treatment date. Defoliation greatly retarded the growth of Spitzenburg shoots, an effect opposite to that noted in the Grimes. The present explanation for these opposite effects of defoliation is as follows: Defoliation accelerated growth in the Grimes shoots because they were nearing the close of their growth period, a time when carbohydrates had accumulated to an extent, which, when considered in relation to the available nitrogen and water, was unfavorable to growth. Defoliation in such a case, by removing the carbohydrate-making machinery, would tend to readjust this relation of carbohydrates to nitrogen in a manner favorable to growth. But defoliation retarded growth of the Spitzenburg shoots probably because the treatment was carried out at a time when they were growing rapidly, and when the available carbohydrates were being effectively utilized for growth. Defoliation in this case would lower the supply of carbohydrates; and any lowering of carbohydrates at this stage of development might be expected to result disadvantageously to growth. The chemical evidence for this assumption will be presented below.

Chemical. Results of chemical analysis are given in Table V and some of the graphs derived from them appear as Figs. 8-10. It was hoped that these data would throw some light upon at least the two following general questions: (1) What is the effect of defoliation on chemical composition of apple shoots? (2) Between the shoots of Grimes and Spitzenburg, are there chemical differences which could be considered significant in explaining the strikingly different effect of defoliation?

As to the general effect of defoliation on the chemical composition, it will be noticed that those substances which tend to increase with the advance of the growing period, such as insoluble solids, starch, hydrolyzable polysaccharides, and total carbohydrates, increase less rapidly in the defoliated shoots than in the checks. Conversely, substances such as water, soluble solids, soluble and insoluble nitrogen, and phloridzin, etc., which tend to decrease during the growing season, decrease less rapidly in defoliated shoots than in the checks. The defoliated shoots thus always have a smaller percentage of the former group and a larger percentage of the latter group than do the checks. This chemical situation between the defoliated and the check shoots reminds one of the differences between the "tip" and the basal regions remarked in the report on

TABLE V. CHEMICAL CHANGES PRODUCED BY DEFOLIATION

Series A.

Date	Treatment	Water	Soluble solids	Insoluble solids	Reducing sugar	Sucrose	Total sugars	Starch	Total polysaccharides	Total carbohydrates	Phlorizdin	Soluble nitrogen	Insoluble nitrogen	Total nitrogen	C/N
Grimes.															
June 6	Checks	63.5	24.5	75.5	1.77	1.88	3.65	2.64	26.9	30.6	5.63	.086	.703	.789	38.8
June 24	Checks	55.3	21.1	78.9	1.44	1.73	3.17	3.28	29.6	32.8	5.11	.059	.461	.520	63.1
	Defoliated	57.4	21.3	78.7	0.90	1.80	1.70	2.93	29.0	30.7	5.79	.083	.548	.632	48.6
July 19	Checks	52.8	17.3	82.7	1.00	1.06	2.06	3.45	31.5	33.6	3.03	.053	.423	.476	70.6
	Defoliated	55.7	19.3	80.7	1.15	1.37	2.52	3.09	30.2	32.7	4.38	.056	.430	.486	67.3
Spitzenburg.															
June 6	Checks	67.1	25.2	74.8	1.59	1.28	2.87	3.12	24.6	27.5	5.19	.101	.807	.908	30.3
June 24	Checks	61.6	23.6	76.4	1.41	1.23	2.64	3.73	26.6	28.2	4.08	.078	.568	.646	43.7
	Defoliated	63.0	23.9	76.1	1.18	1.28	2.46	3.45	25.4	27.9	4.44	.081	.569	.650	42.9
July 19	Checks	58.5	18.7	81.3	1.15	0.97	2.12	3.93	29.2	31.3	2.86	.065	.469	.534	58.6
	Defoliated	59.3	19.2	80.8	1.41	0.99	2.40	3.51	28.8	30.4	2.97	.069	.480	.571	53.3

normal shoots under series C. Evidently the operation of defoliation tends, in a general way, to change the conditions characteristic of an old shoot back to those of a younger one.

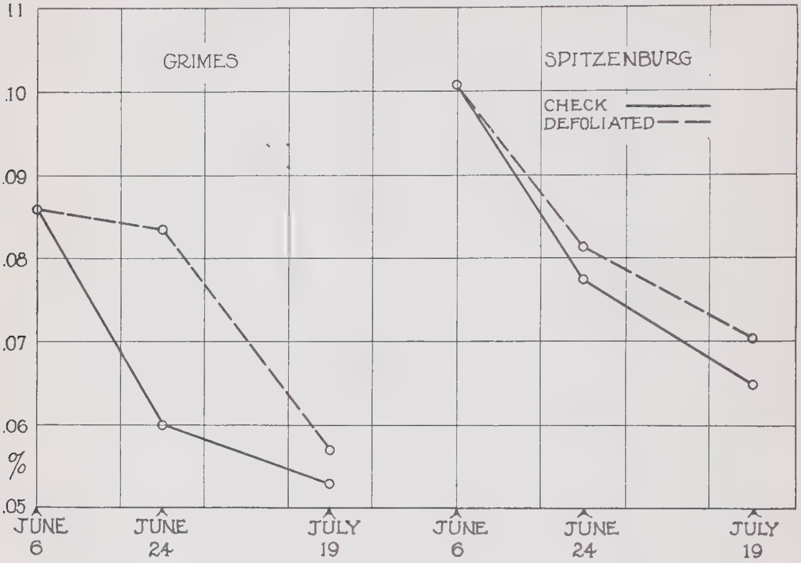

Fig. 8. Effects of defoliation on soluble nitrogen content of apple shoots. Series A.

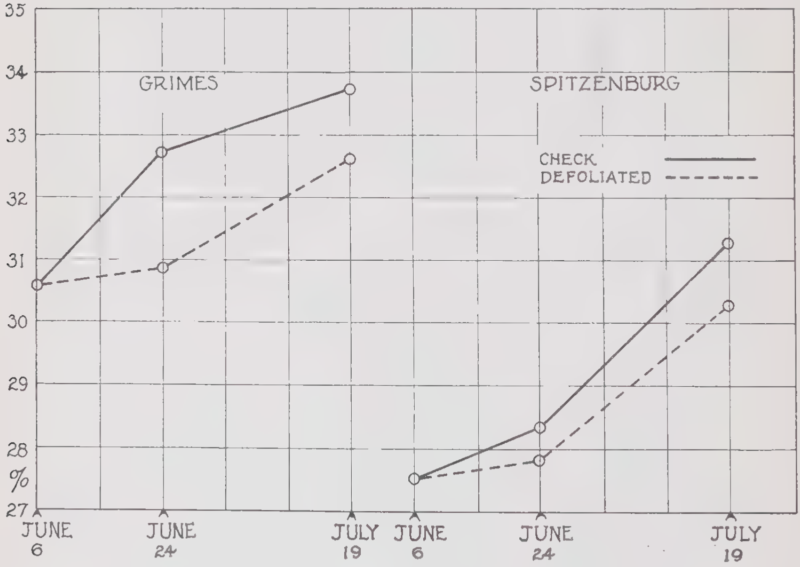

Fig. 9. Effects of defoliation on total carbohydrate content of apple shoots. Series A.

An examination of the chemical findings will now be made with the view of explaining the varietal difference noted in growth response to defoliation. The difficulty of explanation is soon found to lie in the facts that, while defoliation accelerated growth in the Grimes shoots and retarded it in the Spitzenburg, the chemical data for both varieties look very much alike. Take for example the fact that defoliation increased water and nitrogen and decreased carbohydrates in both varieties. It might be supposed then that if growth was increased in one instance it would be in the other also. As a suggestion, however, it may be remarked that Table V and Figs. 8 and 9 show, on any given date, the Grimes to contain higher percentages of carbohydrates and lower percentages of nitrogen than the Spitzenburg. For this reason the ratios of carbohydrates to nitrogen were larger in the Grimes throughout the season. This is shown especially in Fig. 10, where the relative values of the carbohydrate-nitrogen ratios are indicated both by the length of the columns and the spaces between them. It will be noticed that the largest value of the ratio is held by the Grimes check shoots and the smallest by the defoliated Spitzenburg shoots. In order that the above suggestion may be of significance in the present difficulty, it is necessary to assume that the carbohydrate-nitrogen ratio shown for Grimes checks is too large for good growth, and the ratio for the defoliated Spitzenburg shoots, too small for best growth. In the former, nitrogen must be considered limiting and in the latter, carbohydrates. The optimum value of the ratio for growth would, by the same argument, have to be placed near that of the Spitzenburg check shoots. This is shown by the curve representing the relative growth in the different lots, superimposed on the carbohydrate ratio columns in Fig. 10.

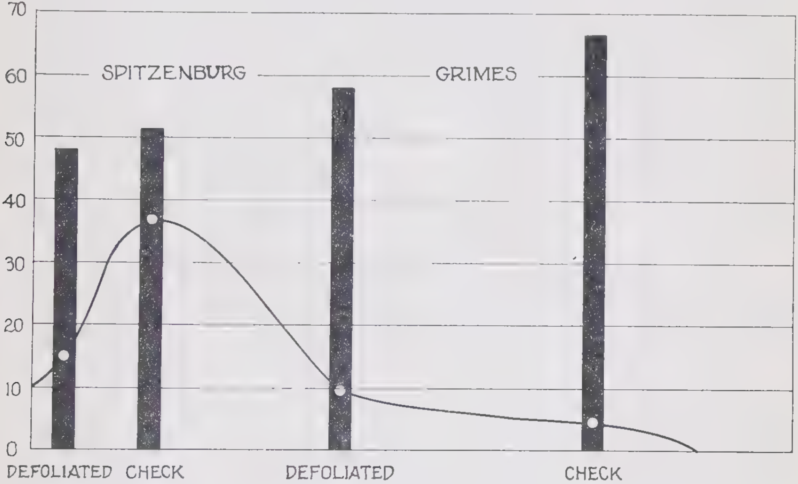

Fig. 10. Showing carbohydrate-nitrogen ratios (columns) and the relative growth in each lot of shoots (curve).

The limits between which any carbohydrate-nitrogen ratio can vary in apple tissue and still permit growth, would seem exceedingly narrow. Evidence from previous work* and other experiments to be reported here tend strongly to bear out this conclusion, but it should be kept constantly in mind that many factors must enter into the determination of the given response of any shoot to defoliation or ringing. Such chemical differences as noted above are, at best, merely suggestive of a final rational explanation of the observed behavior to experimental treatments.

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* Station Bulletin 176.

4. SERIES B

Series B was a study similar to series A, but larger and somewhat older shoots were used and the experimental treatments included both ringing and defoliation. It is considered to be the major experimental work of this bulletin. Besides the addition of ringing and ringing plus defoliation, a more detailed study of the shoots was attempted through a division of the individual shoots into two regions, the "tops" and the "bases." The latter were taken as the lower 6 to 9 centimeters of the shoots, that is to say, below the usual point of ringing or defoliation as previously mentioned (see Fig. 11). The "top" region was that part of the shoot above the point of ringing. These two regions were kept distinct in all chemical analyses. The leaves also were analyzed but handled separately from the wood samples. There was a complete set of leaf samples for the "basal" region of the shoot, since no direct treatment was ever given the "bases," but of course, the leaf samples of the "top" could include only the check and "ringed only" lots.

The experimental treatments and arrangement of material were, briefly, as follows: The varieties used were Grimes and Spitzenburg, as in Series A. There were four experimental lots of shoots: (1) checks, (2) ringed only, (3) defoliated only, and (4) ringed plus defoliated (see Fig. 11). The defoliation and ringing, and the first growth measurements and collection of chemical samples, were carried out June 17-20; and the second and third measurements and collections July 17-18 and August 26, respectively. The shoots were furnished by twelve trees of each variety, employing a total of thirty-six shoots per tree. Of these shoots twelve were used as checks and eight each for "ringed only," "defoliated only," and "ringed plus defoliated." Thus there was a total of about 450 shoots under observation for each variety.

Growth. At the time the experiment was started, it was plain that the Grimes shoots were growing much less rapidly than the Spitzenburg. It is a rather common observation that while the Grimes is likely to make a relatively shorter terminal growth, this growth activity is brought to a close earlier in the summer than in most of the other varieties; certainly this is evident from a comparison of Grimes with Spitzenburg. It was, in fact, on account of the contrasting growth habit of the Grimes and Spitzenburg that they were chosen for the study, for it was hoped that with these varieties it would be possible to examine cases representing the two situations assumed in paragraphs (a) and (b), page 11.

The record of growth for check and treated shoots from June 17 to August 26 is given in Table VI. It may be noted from the record of the check shoots, that the Spitzenburg grew about five times more rapidly than the Grimes. It is evident, too, that the Grimes shoots had completed a considerably larger proportion of their annual growth at the time the experiment was begun.

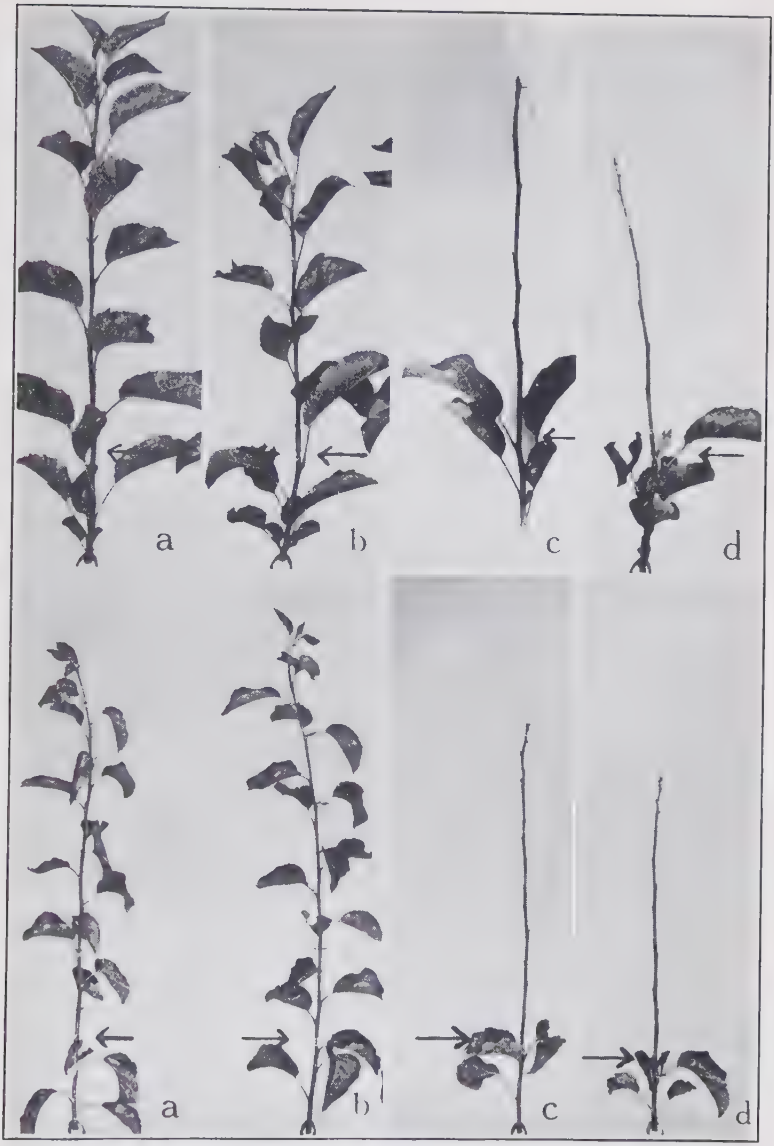

Fig. 11. Photographs of typical shoots of Series B, five weeks after treatment. *Above,* Grimes; *below,* Spitzenburg: (a) checks; (b) ringed only; (c) defoliated only; and (d) ringed plus defoliated. Arrows indicate point of separation between "base" and "top" samples.

As regards the relative growth of the treated shoots, the records show that in the Grimes the "ringed only" grew less and the "defoliated" grew more than the checks, while in the Spitzenburg the situation was reversed; that is, the "ringed only" grew more and the "defoliated only" grew less than the checks. The relative effect of defoliation in the two cases above agree with the growth findings of the experiments of Series A, and relative effects of both ringing and defoliation are practically in complete accordance with results reported for the preliminary experiments on ringing and defoliation. Nor do the results appear to be out of harmony with the tentative explanation offered on page 11. The evidence, favorable or unfavorable to this explanation will have to come from the results of chemical analysis. But to refer again to the growth responses to the different treatments, it is remarkable how quickly and completely ringing plus defoliation stops the growth of the shoots. This sudden stoppage of growth seems to be a universal response to the combination of ringing plus defoliation. It has been so at least in all experiments of the writer and all those reported by Curtis.[1] An explanation of this response based on the chemical study will be offered later.

TABLE VI. EFFECTS OF RINGING AND DEFOLIATION ON GROWTH OF SHOOTS

Series B.

Variety	Treatment	Length June 17	Length July 17	Length Aug. 26	Total increase after treatment	Percentage of increase
		cm.	*cm.*	*cm.*	*cm.*	%
Grimes	Checks	29.3	31.7	33.3	4.0	8.8
	Ringed	29.6	31.2	32.2	2.6	13.6
	Defoliated	28.0	30.7	33.7	5.7	20.4
	Ringed plus defoliated	29.4	30.1	30.6	1.2	4.1
Spitzenburg	Checks	36.8	50.9	58.6	21.8	59.2
	Ringed	38.4	56.0	63.0	24.6	64.0
	Defoliated	39.3	52.6	54.5	15.2	38.6
	Ringed plus defoliated	38.0	38.9	39.2	1.2	3.1

Before leaving the question of growth responses, the behavior of the bases of the experimental shoots should be considered. The superficial responses of the bases to the treatment given the tops were, for each treatment, as follows:

1. Checks—showed no sign whatsoever of swelling of buds in the axils of the basal leaves.

2. Ringed only—one to three of axillary buds per shoot swelled and frequently one or more broke, sometimes producing shootlets 1 to 3 cm. long.

3. Defoliated only—mostly no indication of buds swelling in the basal axils, but in a few instances these buds had enlarged noticeably.

4. Ringed plus defoliated—nearly all the shoots renewed growth activity in the basal portions, similar to the ringed only, but this growth renewal was more in quantity, as many of these new shoots became 4 to 7 cm. long (see Fig. 11).

Reference will be made again to the above regenerative activities where the results of the chemical analyses of the basal portions of the shoots are discussed.

Chemical analyses. The chemical data of Series B will be presented under the two distinct headings, "tops" and "bases." These two groups will be further subdivided into "stems" and "leaves." The analyses of the stems of both portions, however, are considerably more complete, and practically all the emphasis is placed upon them.

"Tops." *Stem samples.* The analyses of the stems of top portions of the shoots are given in Tables VII and VIII and certain graphs derived from them in Figs. 12-18.

An examination of the above tables and illustrations will disclose several interesting chemical relationships among the shoots receiving different treatments. One of the most easily observed situations is with regard to the behavior, in the treated shoots, of the two large groups of substances, which were classified on basis of their normal tendency, either to increase or decrease during the growing season. Observing the analytical data for the check shoots of both varieties, it will be found that nearly all substances estimated fall readily into one of the two groups as follows:

(1) Those substances which tend to diminish through the season are water, soluble solids, reducing sugars, total sugars (?), phloridzin, and nitrogen.

(2) Those substances which tend to increase through the season are insoluble solids, sucrose, starch, pentosans, total hydrolyzable polysaccharides, and total carbohydrates.

If these groups of substances are examined as to their behavior in the shoots which were ringed only, and defoliated only, it will be found that those of group 1 are less abundant in the ringed and more abundant in the defoliated shoots than in the checks. On the other hand those of group 2 are more abundant in the ringed and less abundant in the defoliated as compared with the checks.

In general, the substances which tend to decrease during the season in the checks are apparently essential to active growth. In this connection it will be noticed that the glucoside phloridzin, as regards its fluctuations in amount, behaves much like nitrogen. Phloridzin is not usually considered a vital substance in the metabolism of plants, yet its behavior here justifies some attention. The fact that phloridzin is present in relatively large quantities in the growing shoots, especially near the growing point (see Fig. 5) and that it decreases during the growing season almost parallel with nitrogen and the growth rate, would indicate that, even though it may not have a direct role in such metabolic centers, it probably has an important indirect one, if nothing more than as a temporary repository of some harmful by-product of active metabolism. Attention is called also to the interesting behavior of phloridzin in the shoots receiving both ringing and defoliation. Here, like water and nitrogen, the percentage of phloridzin increases considerably through the season (see Fig. 15).

In examination of the chemical findings in this experiment, it should be remembered that these data appertain only to shoots from the middle of their growing period to the close of it. Thus there is excluded entirely the early stage of growth when most of the elaborated food is coming from the last year or older portions of the branch. To bring the present chemical findings into line with the observed growth responses,

TABLE VII. CHEMICAL CHANGES PRODUCED BY RINGING AND DEFOLIATION
Analysis of the Upper Stems. Grimes. Series B.

Date	Treatment	Water	Soluble solids	Insoluble solids	Reducing sugars	Sucrose	Total sugars	Starch	Pentosans	Polysaccharides	Total carbohydrates	Phloridzin	Soluble nitrogen	Insoluble nitrogen	Total nitrogen	C/N	Starch nitrogen
June 23	Checks	59.3	28.7	71.3	2.55	0.00	2.55	2.96	17.7	18.9	21.4	5.95	.071	.556	.627	34.1	4.7
July 13	Checks	56.2	23.9	76.1	1.76	0.08	1.84	3.90	19.1	21.3	23.1	3.67	.062	.466	.528	43.7	7.4
	Ringed	52.8	24.9	75.1	1.99	0.07	2.06	4.62	19.0	23.2	25.3	3.56	.060	.420	.480	52.6	8.1
	Defoliated	56.4	24.9	75.1	1.44	0.04	1.48	2.66	17.7	19.3	20.8	6.33	.072	.500	.572	36.4	4.7
	Ringed plus defoliated	63.6	25.7	74.3	1.10	0.08	1.18	2.46	19.2	15.5	16.7	7.75	.163	.525	.688	25.0	3.6
August 26	Checks	52.0	21.1	78.9	1.24	0.06	1.30	3.62	19.6	21.6	22.9	4.01	.060	.451	.511	44.8	7.1
	Ringed	57.1	22.6	77.4	1.50	0.05	1.56	4.46	16.5	23.7	25.3	4.72	.059	.374	.433	58.5	10.3
	Defoliated	55.4	24.0	76.0	1.91	0.06	1.97	3.44	18.3	19.3	21.3	4.25	.063	.420	.483	44.1	7.1
	Ringed plus defoliated	58.0	24.9	75.1	2.25	0.09	2.34	3.08	18.1	18.4	20.8	5.27	.084	.460	.544	38.2	5.6

TABLE VIII. CHEMICAL CHANGES PRODUCED BY RINGING AND DEFOLIATION
Analysis of the Upper Stems. Spitzenburg. Series B.

Date	Treatment	Water	Soluble solids	Insoluble solids	Reducing sugar	Sucrose	Total sugars	Starch	Pentosans	Total polysaccharides	Total carbohydrates	Phloridzin	Soluble nitrogen	Insoluble nitrogen	Total nitrogen	C/N	Starch nitrogen
June 23	Checks	63.8	29.2	70.8	1.58	0.29	1.87	1.24	16.1	17.5	19.4	2.49	.124	.784	.908	21.4	1.4
July 13	Checks	62.1	24.7	75.3	1.30	0.26	1.56	3.12	18.4	19.6	21.2	2.02	.094	.560	.654	32.4	5.4
	Ringed only	57.9	24.4	75.6	1.49	.20	1.69	3.59	18.5	21.7	23.5	1.70	.076	.531	.607	38.7	5.3
	Defoliated only	63.1	24.0	76.0	1.34	.20	1.54	2.08	18.8	17.8	19.3	1.70	.069	.603	.672	28.8	3.1
	Ringed and defoliated	65.2	26.2	73.8	0.76	.20	0.96	1.45	18.4	15.4	16.4	2.88	.168	.580	.748	22.3	2.0
August 26	Checks	55.6	19.9	80.1	1.11	.35	1.46	3.64	19.2	22.3	23.8	2.10	.060	.397	.457	52.1	7.9
	Ringed only	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Defoliated only	57.6	19.8	80.2	1.18	.23	1.41	2.86	20.0	20.0	21.4	1.97	.056	.414	.470	45.5	6.1
	Ringed and defoliated	68.0	25.3	74.7	1.14	.31	1.45	2.21	18.1	18.2	19.7	4.04	.089	.473	.562	35.1	4.0

TABLE IX. CHEMICAL CHANGES PRODUCED BY RINGING AND DEFOLIATION

Analysis of Upper Leaves. Series B.

Treatment and date	Grimes					Spitzenburg				
	Water	Pentosans	Total nitrogen	Total carbohydrates	C/N	Water	Pentosans	Total nitrogen	Total carbohydrates	C/N
June 23										
Checks	63.0	7.4	1.58	22.7	14.4	69.1	8.2	1.84	19.8	10.8
July 13										
Checks	60.9	7.2	1.54	22.2	14.4	67.9	8.0	1.76	20.0	11.4
Ringed only	54.1	7.0	1.46	32.9	22.6	62.5	8.4	1.24	29.3	23.6
August 6										
Checks	58.5	7.9	1.50	21.9	14.6	65.8	5.4	1.69	21.2	12.5
Ringed only	51.7	9.5	1.00	29.2	29.2	59.3	8.1	0.97	27.2	28.1

it will be necessary to take into consideration the probable situation as regards the manufacture and movement of elaborated plant foods in the shoots during the particular portion of the growing season included by this study. Accordingly, let us assume that from the height of the growing season to its close, practically all the carbohydrate materials for the growing point are derived from the activities of the leaves of the shoot itself. Then the inference may be drawn that ringing will tend to increase the carbohydrates in the shoot and defoliation to decrease them. Tables VII and VIII and Fig. 16 offer evidence that this is actually what happened. Along with the increase or decrease of carbohydrates, the ratio of carbohydrates to nitrogen is found to rise or fall in value (see Fig. 17). An interpretation of the observed growth responses to ringing and defoliation may be based on the principle that if ringing retards growth it is because the carbohydrate-nitrogen ratio is thereby made unfavorably large, and if, on the other hand, ringing accelerates growth, it does so because the ratio was previously too small for best growth and is thus favorably increased. Correspondingly, if defoliation retards growth it is because the ratio is thereby made unfavorably small, but if it accelerates growth it is because the ratio was previously too large, so that a decrease is favorable to growth. The record of growth responses in Table VI indicated that ringing may accelerate growth in mid-season but retard it later, the reverse being true for defoliation. These reversals of the growth response may be explained on the ground that in mid-season ringing can accelerate and defoliation retard growth because the carbohydrates at that time have not quite reached the optimum percentages (in relation to the nitrogen supply) in the shoots. Later in the season, ringing will retard and defoliation accelerate growth because the carbohydrate content has come to exceed the optimum for best growth activities. While none of the foregoing assumptions, as they apply specifically to the present report, can be considered as established, they do at least tend to unify in a large measure the various observed growth responses and the general chemical changes concurring with them.

The striking effects on growth of ringing plus defoliation may now be considered from the standpoint of the chemical changes induced. Referring to the data in Tables VII and VIII, we find that the ringed and defoliated shoots have the least carbohydrate and the highest percentages of water and nitrogen recorded for any other treatment, including the checks. Accordingly, too, these shoots have the smallest carbohydrate-nitrogen ratio. The sudden diminution of carbohydrates here would seem to follow inevitably as a result of the removal of the carbohydrate-making machinery through defoliation, and the shutting off of the supply from below by ringing. The metabolic process of the shoot

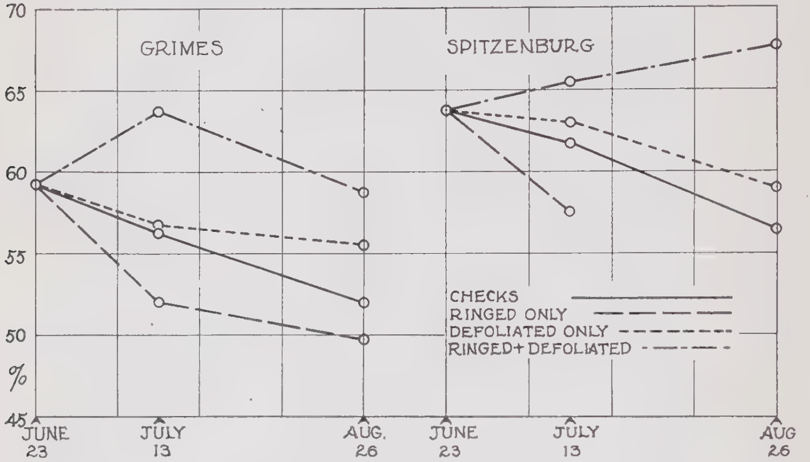

Fig. 12. Effects of ringing and defoliation on water content of apple shoots. Top, stems. Series B.

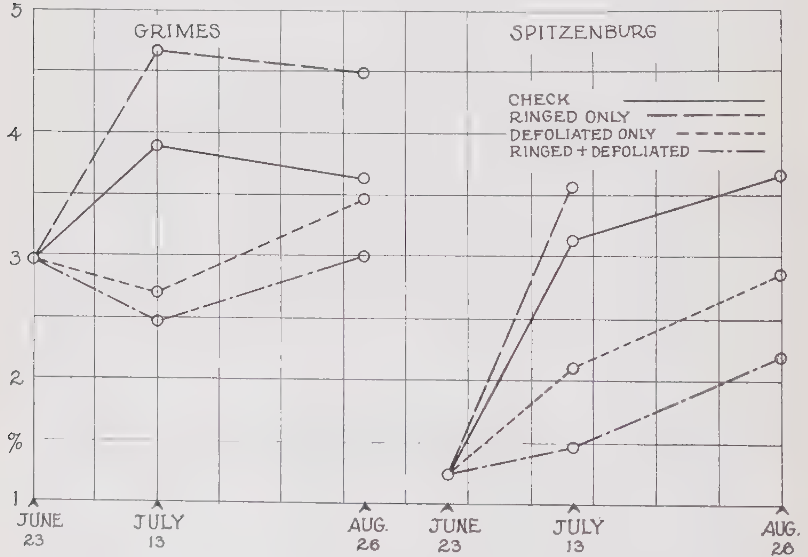

Fig. 13. Effects of ringing and defoliation on starch content of apple shoots. Top, stems. Series B.

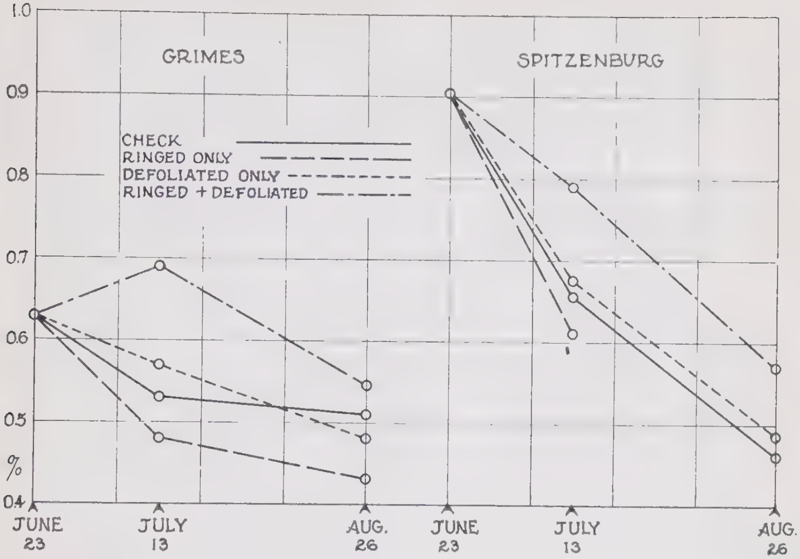

Fig. 14. Effects of ringing and defoliation on total nitrogen content of apple shoots. Top, stems. Series B.

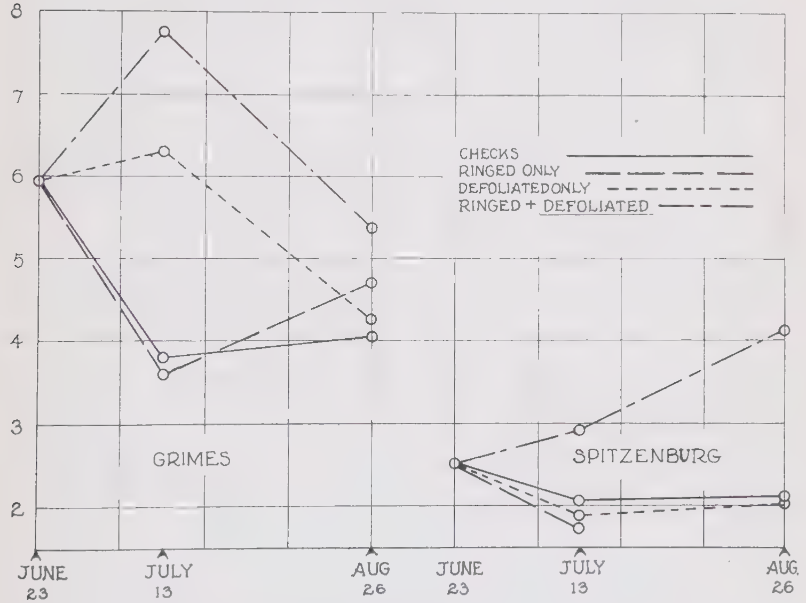

Fig. 15. Effects of ringing and defoliation on phloridzin content of apple shoots. Top, stems. Series B.

must then use up the available supply of carbohydrates very quickly. That this great check to growth is due to a deficit of carbohydrates seems more likely on the ground that water and nitrogen, the two commonly limiting factors to growth, are more abundant in these shoots than in those of any other treatment. To translate this idea over to the carbohydrate and nitrogen relations, it may be said that ringing plus defoliation causes a rapid fall in the value of the ratio below that necessary for growth activity.

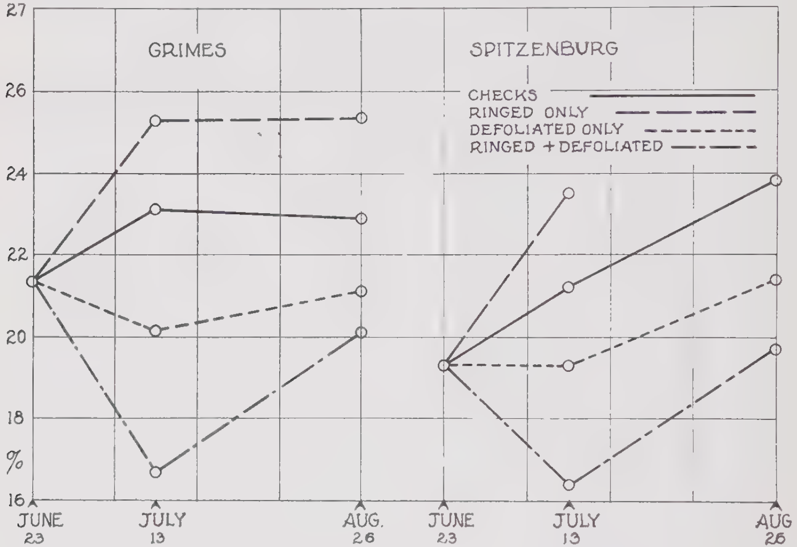

Fig. 16. Effects of ringing and defoliation on total carbohydrate content of apple shoots. Top, stems. Series B.

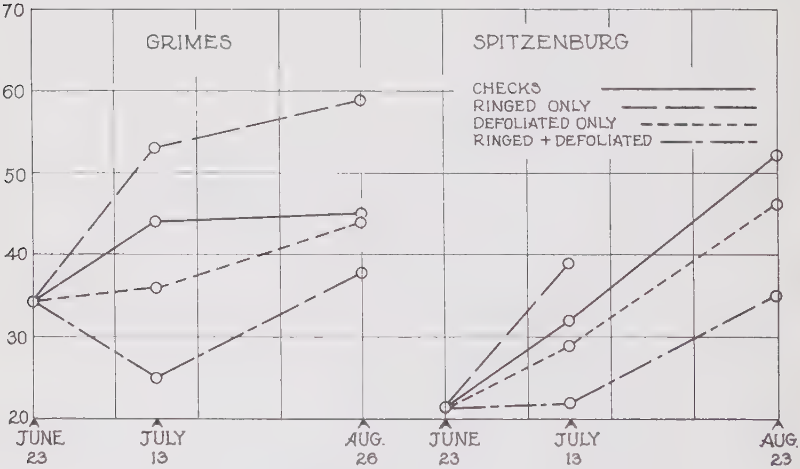

Fig. 17. Effects of ringing and defoliation on carbohydrate-nitrogen ratios content of apple shoots. Top, stems. Series B.

The sudden check to growth by ringing and defoliation was observed in every experiment performed. Curtis[1] also records the same response to this particular treatment. He is inclined to explain it, however, on the grounds that the ringed and defoliated shoots have not sufficient water, seeing that they have a lower carbohydrate content and a lower osmotic pressure, which he observed. But a calculation of the water content of these shoots, from the data this investigator presents in Table V,* for example, shows that the relative water content of his ringed and defoliated shoots is in full agreement with the present findings.

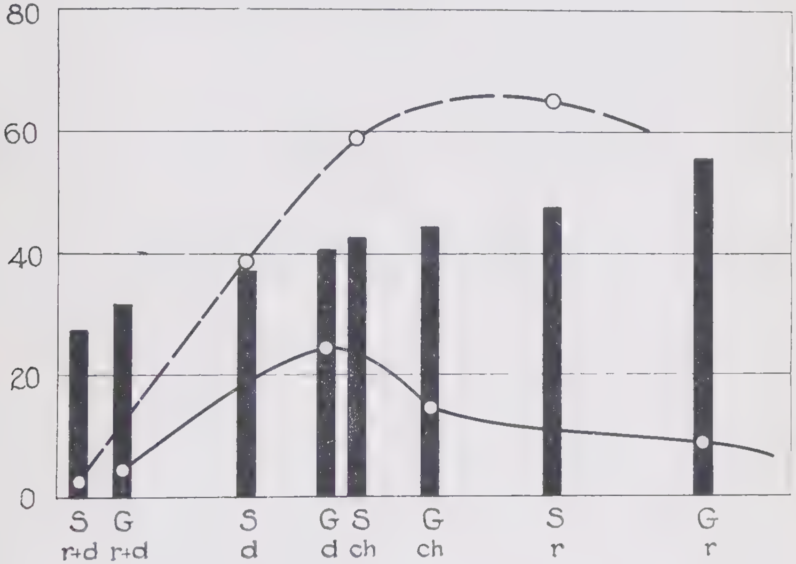

Fig. 18. Showing carbohydrate-nitrogen ratios (columns) and the relative growth of shoots. Tops. Series B. (S) Spitzenburg; (G) Grimes; (ch) checks; (r+d) ringed plus defoliated; (d) defoliated only; (r) ringed only.

Another point to consider here with reference to the chemical data is the relative behavior of Grimes and Spitzenburg to the same treatments. Growth in the Grimes shoots was retarded by ringing and accelerated by defoliation, the reverse being true for Spitzenburg. The question is: Are there chemical differences between the two varieties that might be considered significant enough to account for these remarkable differences in response to the same treatment? It is feared that it will be taken as begging the question to attempt to account for the opposite behaviors of the two varieties by means of such differences as are revealed by the chemical analyses. Attention will be called, however, to two or three points which may be worth consideration. First, it will be noticed that, taking the results of the chemical analyses as a whole, the Grimes shoots have somewhat less water, soluble solid, nitrogen, etc., and more insoluble solids and carbohydrates and a larger carbohydrate-nitrogen ratio than the Spitzenburg. Were these differences significant, an explanation would at once suggest itself. To make this matter clearer, Fig. 18 was prepared from the growth and chemical data. In this figure the columns indicate the carbohydrate-nitrogen ratios of all the variously treated shoots. The differences in the values of the ratios (as in Fig. 10) are represented both by the length of the columns and the distances between them. The relative growths made after treatment are superimposed on the columns as curves connecting the columns of the same variety. The maximum growth rates for the two varieties are not found to occur at quite the same carbohydrate-nitrogen ratio value, the Spitzenburg having a somewhat larger value at the best growth rate. Hence it is likely that if there is any significance in the chemical findings as accounting for the differences in behavior, it must lie in some characteristic varietal requirement.

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* Cf. Curtis[1] p. 107.

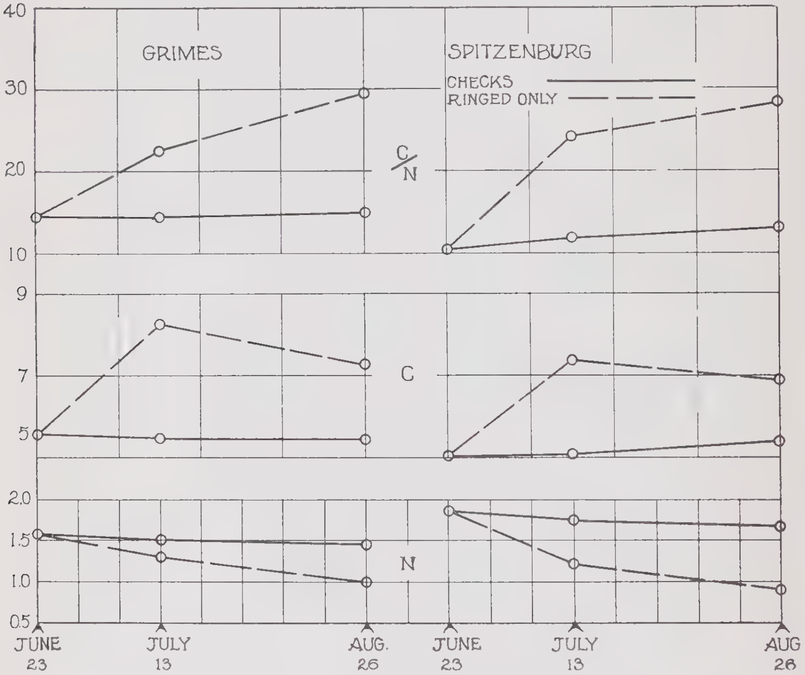

Fig. 19. Effects of ringing and defoliation on total nitrogen, total carbohydrates, and carbohydrate-nitrogen ratios. Top, leaves. Series B.

Leaf samples. The chief aim in preserving and analyzing the leaves in these experiments was to test them as indicators of the conditions within the stem. It was thought that if they follow in general the behavior of the stem itself, it would be a fact well worth knowing on account of the relative economy they offer in collection and analysis.

The analyses here presented are considerably less detailed than those of the stem tissue including as they do, estimations only of water, total nitrogen, pentosans, and total carbohydrates. The results are summarized in Table IX, and graphs for nitrogen, carbohydrates, and carbohydrate-nitrogen ratio are presented in Fig. 19. The leaves of both varieties give practically the same results. Those of the ringed shoots have less water and nitrogen, and much more total carbohydrates than the checks. The pentosans fluctuate rather irregularly, although there is possibly a tendency for them to be more abundant in the ringed shoots. The carbohydrate-nitrogen ratio is very greatly increased by ringing. These chemical changes seem to be in general accord in quality, though they exceed in quantity, those observed for the stems of the same shoots.

Bases. *Stem samples.* The results of the chemical analyses of the stems of the basal portions of the shoots are given in Tables X and XI and some of the results are further illustrated in Figs. 20-23.

A general view of the data will show that in both varieties the check shoots and the ringed plus defoliated represent the extremes as regards most of the chemical changes recorded. The "defoliated only" and "ringed only" shoots fall between the above, so that for most of the chemical changes these four lots of shoots keep among themselves the following order: checks, defoliated only, ringed only, and ringed plus defoliated. As regards the amount of most substances examined, the above order thus indicates either an ascending or descending variation of the substance in question. To illustrate: water, soluble solids, nitrogen, and phloridzin *increase* through the different treatments in the order named, while a corresponding *decrease* through the series is noted for such substances as insoluble solids, total sugars, polysaccharides, total carbohydrates, and carbohydrate-nitrogen ratio. A number of irregularities and exceptions will be noticed, however, with the sugars, starch, pentosans, and phloridzin, etc. But the relative order mentioned certainly holds regularly enough to be of significance. The most remarkable effect produced is the rather large increases in percentages of nitrogen in the bases of the "ringed only" and "ringed plus defoliated" shoots (see Fig. 20). The total carbohydrates vary in the opposite direction but the changes are relatively not so great (see Fig. 21). As a result of this interplay of carbohydrate and nitrogen, the carbohydrate-nitrogen ratios vary strikingly among the different treatments (see Fig. 22), so that in either variety the ratio in the "ringed plus defoliated" bases is only about 60 percent of that in the checks.

It might be of interest now to attempt to relate chemical findings to the observed regenerative activities of the basal portions. On page 26 it was recorded that in respect to renewal of growth in the bases, the order of *increasing* activity for the different treatments was as follows: checks, defoliated only, ringed only, and ringed plus defoliated. This is the same order as established by chemical analysis and it may have considerable significance. The relation between the regenerative activities and carbohydrate-nitrogen ratios is illustrated in Fig. 23, which corresponds exactly to Fig. 18 both as to scale and general makeup, and should be studied with reference to it. It will be noticed that the carbohydrate-nitrogen ratios in the bases of the checks and the "defoliated only," where there was no renewed growth, stand outside and to the right of the area where regeneration of the bases (see Fig. 23) and growth of the tops (see Fig. 18) is most active. The ratio of the bases of the Grimes shoots which were ringed only lie very close, however, to that of defoliated only. Again, the carbohydrate-nitrogen ratios of those bases which showed vigorous regeneration, correspond rather closely with best growth area of the tops (Fig. 18). The factors usually

TABLE X. CHEMICAL CHANGES PRODUCED BY RINGING AND DEFOLIATION.

Analysis of Bases. Grimes. Series B.

Date	Treatment	Water	Soluble solids	Insoluble solids	Reducing sugar	Sucrose	Total sugars	Starch	Pentosans	Total polysaccharides	Total carbohydrates	Phloridzin	Soluble nitrogen	Insoluble nitrogen	Total nitrogen	C/N	Starch / nitrogen
June 23	Checks	55.7	23.5	76.5	2.40	.04	2.44	3.26	19.1	21.3	23.7	5.42	.046	.405	.451	52.5	7.2
July 13	Checks	51.5	20.0	80.0	1.89	.02	1.91	3.69	19.7	21.6	23.5	3.88	.044	.364	.408	57.6	9.0
	Ringed	52.5	23.2	76.8	1.42	.02	1.44	3.65	19.4	21.5	22.9	4.51	.055	.435	.490	46.7	7.5
	Defoliated	52.1	21.0	79.0	1.37	.03	1.40	2.68	19.5	21.4	22.8	4.65	.067	.437	.504	45.2	5.3
	Ringed plus defoliated	52.5	22.3	77.7	1.19	.07	1.26	2.62	19.5	21.3	22.6	4.14	.083	.463	.546	41.4	4.8
August 26	Checks	48.6	18.3	81.7	1.18	.05	1.23	3.44	19.9	23.9	25.1	3.29	.046	.346	.392	64.0	8.8
	Ringed	51.0	20.4	79.6	1.50	.07	1.57	3.29	18.7	20.0	21.6	3.65	.053	.385	.438	49.3	7.5
	Defoliated	50.3	20.3	79.7	1.58	.05	1.63	3.72	19.6	21.1	22.6	4.01	.049	.356	.405	55.8	9.1
	Ringed plus defoliated	52.4	21.1	78.9	1.52	.07	1.59	3.60	17.7	18.9	20.5	3.54	.078	.401	.479	42.8	7.5

TABLE XI. CHEMICAL CHANGES PRODUCED BY RINGING AND DEFOLIATION

Analysis of Bases. Spitzenburg. Series B.

Date	Treatment	Water	Soluble solids	Insoluble solids	Reducing sugars	Sucrose	Total sugars	Starch	Pentosans	Total polysacchrides	Total carbohydrates	Phloridzin	Soluble nitrogen	Insoluble nitrogen	Total nitrogen	C/N	Starch / nitrogen
June 23	Checks	58.9	24.1	75.9	1.40	0.36	1.76	2.48	17.6	19.6	22.4	2.71	.074	.465	.539	41.6	4.6
July 13	Checks	53.8	19.1	80.9	1.39	0.27	1.66	2.40	19.4	20.9	22.6	2.11	.064	.392	.456	49.5	5.3
	Ringed	55.8	19.5	80.5	0.80	0.21	1.01	3.09	19.6	19.7	20.7	1.84	.143	.518	.761	27.2	4.1
	Defoliated	56.4	20.4	79.6	1.10	0.22	1.32	2.19	20.2	20.2	21.5	2.20	.087	.443	.530	40.6	4.1
	Ringed and defoliated	57.7	21.7	78.3	0.50	0.20	0.70	3.21	18.9	19.9	20.6	2.17	.200	.583	.783	26.3	4.0
August 26	Checks	51.2	17.3	82.7	1.05	0.22	1.27	3.46	20.8	22.8	24.1	1.90	.040	.318	.358	67.3	9.7
	Ringed	53.9	20.3	79.7	1.31	0.17	1.48	2.80	19.1	20.8	22.3	2.33	.065	.395	.460	48.5	6.1
	Defoliated	54.1	18.5	81.5	1.14	0.26	1.40	1.51	20.9	21.9	23.3	1.85	.052	.344	.396	58.9	3.8
	Ringed and defoliated	55.5	22.5	77.5	0.91	0.28	1.19	3.59	20.0	21.4	22.6	2.37	.088	.451	.539	41.9	6.6

TABLE XII. CHEMICAL CHANGES PRODUCED BY RINGING AND DEFOLIATION

Analysis of Basal Leaves. Series B.

Treatment and date	Grimes Water	Grimes Pentosans	Grimes Total nitrogen	Grimes Total carbohydrates	Grimes C/N	Spitzenburg Water	Spitzenburg Pentosans	Spitzenburg Total nitrogen	Spitzenburg Total carbohydrates	Spitzenburg C/N
June 23										
Checks	61.5	8.1	1.50	22.5	15.0	67.7	9.9	1.54	20.6	13.3
July 13										
Checks	60.4	7.5	1.53	22.8	14.9	66.3	9.0	1.57	21.5	13.7
Ringed	65.4	7.4	1.66	21.7	13.0	75.0	9.2	1.66	20.1	12.1
Defoliated	61.6	7.8	1.56	20.7	13.3	66.8	8.5	1.66	20.4	12.3
Ringed and defoliated	68.1	7.5	1.72	20.1	11.8	76.3	1.6	1.79	21.0	11.7
August 26										
Checks	58.2	7.3	1.49	22.9	15.3	65.4	5.5	1.36	21.4	15.7
Ringed	60.3	8.4	1.53	21.3	13.9	66.0	6.5	1.42	21.2	13.9
Defoliated	58.8	8.3	1.45	21.4	14.7	63.6	3.7	1.45	21.1	14.5
Ringed and defoliated	64.2	7.7	1.57	20.8	13.2	66.1	5.3	1.52	20.5	12.5

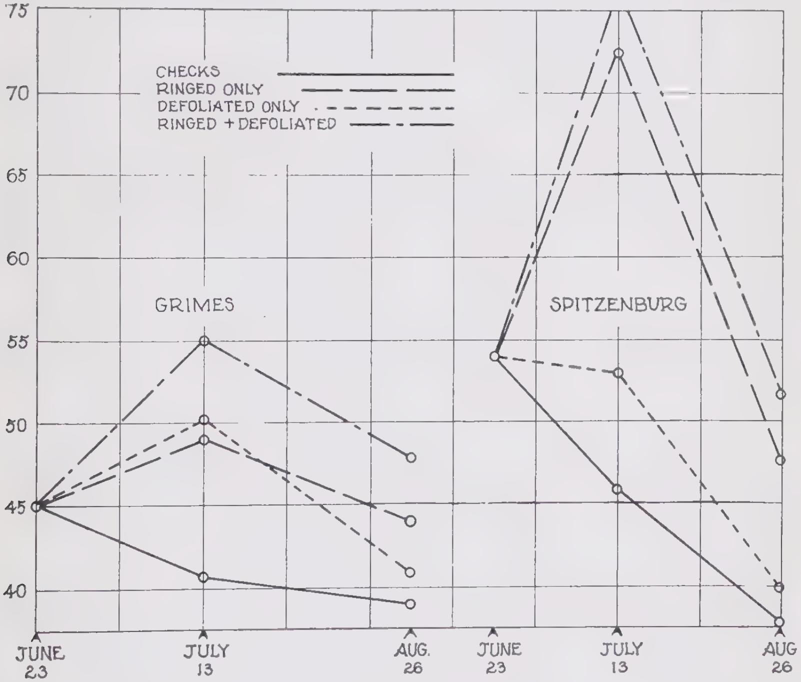

Fig. 20. Effects of ringing and defoliation on total nitrogen content. Base, stems. Series B.

considered under the topic "growth correlations" are of course involved here, and are probably important enough in case of the defoliated shoots of both varieties to be the controlling influence (i.e., in preventing regeneration), seeing that the Grimes "ringed only" showed considerable

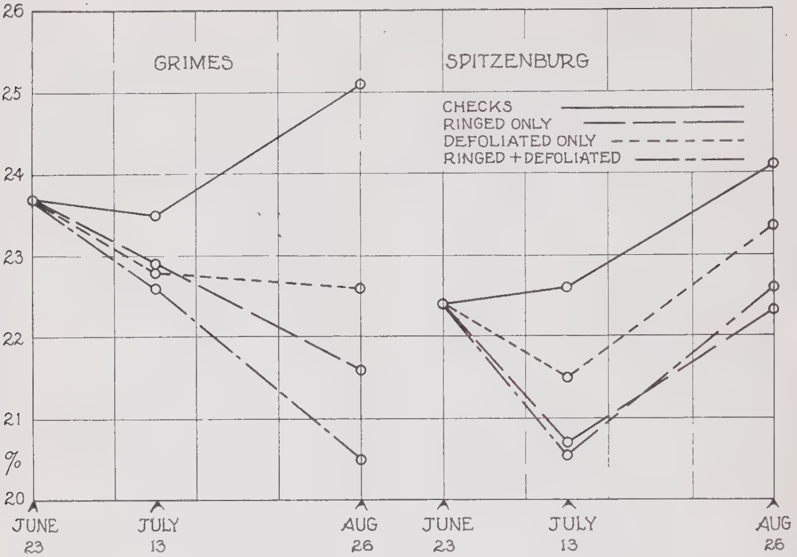

Fig. 21. Effects of ringing and defoliation on total carbohydrate content. Base, stems. Series B.

regenerative activity. But with or without the influence of "growth correlation" there seems to be strong evidence pointing to the importance of a correct and rather definite relation between carbohydrates and nitrogen, which for brevity and convenience may be referred to as a "ratio."

The results of the chemical analyses of the basal portion of the shoots of Series B have a direct bearing on the growth responses obtained by pruning. When a shoot is severely headed, a situation must

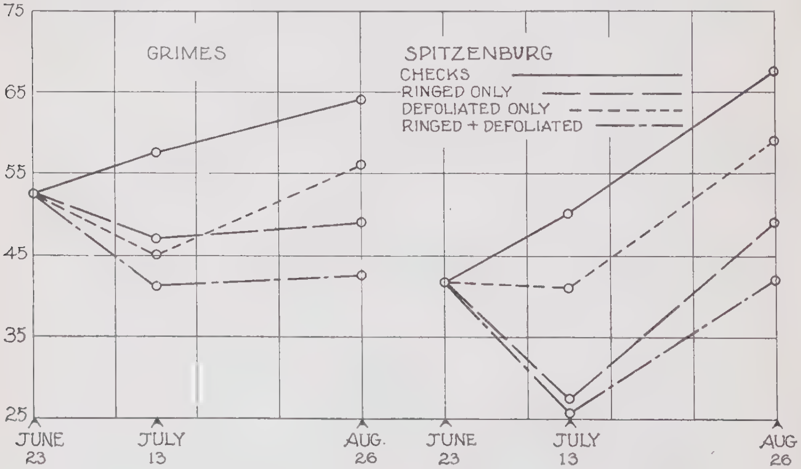

Fig. 22. Effects of ringing and defoliation on carbohydrate-nitrogen ratios content. Base, stems. Series B.

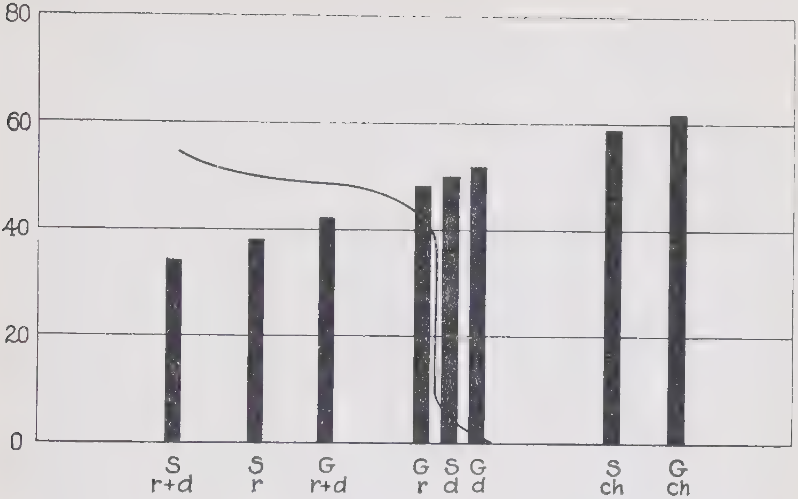

Fig. 23. Showing carbohydrate-nitrogen ratios (columns) and approximate relative regenerative activity (curve) in bases of shoots of Series B. Uniform with Fig. 18.

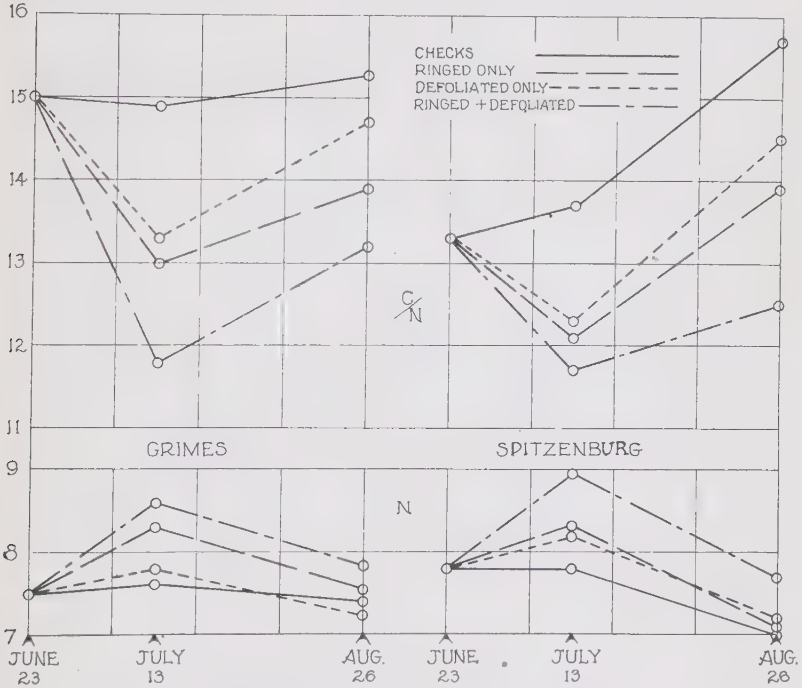

Fig. 24. Effects of ringing and defoliation on total nitrogen (N X 5) content and carbohydrate-nitrogen ratios of apple shoots. Base, leaves. Series B.

rapidly develop in the stub very similar to that recorded for the bases of the "ringed only" and the "ringed plus defoliated" shoots. A complete removal of the upper portion of the shoot, as by pruning, would likely be but slightly more severe than a ringing plus defoliation. In such case, with pruned stubs added to our series, the order as regards the increasing amount of chemical changes brought about in the bases would probably be: checks, defoliated only, ringed only, and ringed plus defoliated and pruned.

Leaf samples. The method of analysis employed for the leaves of the base of the shoots was the same as mentioned for the leaves of the top portions. The results are given in Table XII and Fig. 24.

These data show that the variations of water, nitrogen, and carbohydrates in the basal leaves are in rather close agreement with those found in the stems themselves. Throughout the different treatments the chemical changes in leaves and stems are about the same in kind and degree.

5. SERIES E

Series E was a study of the effects of ringing in relation to stage of development of the shoot.

The ringing experiments carried out in the preliminary study in 1920 and in Series B of 1921, were always on shoots which had reached either the middle of their growth period or were well toward the end of it, consequently the early stages of shoot development still remained unobserved. But strikingly different growth responses to ringing, both as to quantity and quality, were recorded from the above experiments and an explanation for these differences was outlined in the preceding pages. But, as mentioned, the preceding experiments, while allowing the outlining of an explanation, did not systematically show the range of effects to be expected from either ringing or defoliation throughout the growing season; in fact, rather sporadically only, they furnished specific examples from the period of about mid-season to the end of it. The need of more information covering the early part of the growing season, at least, thus became apparent.

The studies to be reported now under the heading, Series E, were undertaken with the aim of following closely the superficial effects of ringing on growth at different stages of shoot development; the general plan of the experiment being to select a large number of shoots very early in the season, and to ring different lots of these at approximately ten-day intervals throughout the principal part of the growing season, keeping record of their subsequent performances.

For this work 30 Grimes and 33 Arkansas Black trees were chosen to furnish the material. These trees were nine years old and were selected of a size which would allow them to furnish readily 50 or more shoots per tree. The number of shoots actually used on each tree was 32, one-half of which were untreated checks. On each date of ringing, eight shoots per tree were carefully selected, tagged, and measured, after which four were ringed just below the base of the new shoot in the growth of the previous season (see Fig. 25). On every ringing date, therefore, 240 Grimes and 264 Arkansas Black shoots were brought under observation, one-half of which were checks. There were four ringing dates as follows: May 9, May 21, May 31, and June 27. (See Fig. 25 for appearance of shoots on each ringing date.) The first three lots received four measurements subsequent to the ringing date, and the last lot, two measurements. In Tables XIII-XV, where the results are summarized, only the first two measurements for each ringing period are included. All further discussion of these results will be based on the performance of the shoots during the first ten to fifteen days after ringing. The results of later measurements tell the same general story but taken as a whole, do not appear to tell it so clearly. Table XIII gives the averages of all shoots of both varieties, and in this connection it should be kept in mind that every growth value recorded in this table is the average performance, either of 120 Grimes or 132 Arkansas Black shoots.

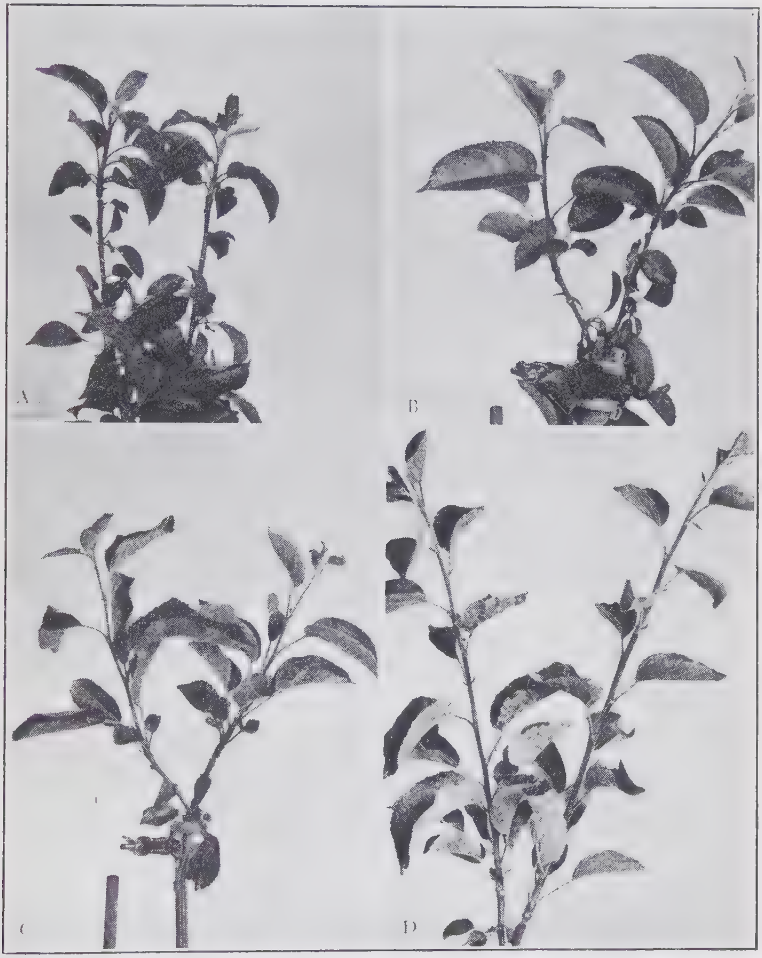

Fig. 25. Showing size and appearance of shoots on different ringing dates. Arkansas Black. Series E. (A) May 9; (B) May 21; (C) May 31; and (D) June 27.

A glance at this table shows that both varieties behaved much alike, and that on some dates ringing retarded and on others accelerated growth, or retarded it very slightly. Considering the Arkansas Black shoots, for example, on May 9 ringing retarded growth 13 percent;* on May 21 ringing retarded growth considerably less, in fact perhaps accelerated it about 3 percent; but after May 31 there was retardation again. The percentage values used above (derived by subtracting the percentage of growth of the ring shoots from the percentage of growth of the checks) do not properly take into consideration the proportional effect of ringing to the normal growth of check shoots. It was thought that a better indicator of the effect of ringing would be this same dif-

TABLE XIII. EFFECTS OF RINGING ON GROWTH OF SHOOTS

Summary of all trees. Series E.

Variety	Treatment	Date of ringing											
		May 9						May 21					
		Length of shoots			Increase from 5/9 to 5/21.	Difference check minus ringed	Coefficient of relative growth	Length of shoots			Increase from 5/21 to 5/31	Difference check minus ringed	Coefficient of relative growth
		5/9	5/21	5/31				5/21	5/31	6/15			
		cm.	cm.	cm.	%	%		cm.	cm.	cm.	%	%	
Grimes	Checks	8.5	15.1	19.5	77.6			14.8	19.1	22.6	29.1		
	Ringed	8.6	14.3	17.6	66.3	+11.3	+15	15.4	20.3	24.1	31.8	—2.7	—9
Arkansas Black	Checks	4.7	9.7	13.1	107.0			10.9	14.9	21.6	36.7		
	Ringed	4.9	9.5	12.8	94.0	+13.0	+12	11.0	15.4	22.8	40.0	—3.3	—9

Variety	Treatment	Date of ringing											
		May 31						June 27					
		Length of shoots			Increase from 5/31 to 6/15	Difference check minus ringed	Coefficient of relative growth	Length of shoots			Increase from 6/27 to 7/17	Difference check minus ringed	Coefficient of relative growth
		5/31	6/15	6/27				6/27	7/17	8/13			
		cm.	cm.	cm.	%	%		cm.	cm.	cm.	%	%	
Grimes	Checks	19.5	23.4	24.6	20.0			25.0	26.8	27.2	7.2		
	Ringed	19.9	23.6	24.7	18.6	+1.4	+7	26.6	27.4	27.6	3.1	+4.1	+57
Arkansas Black	Checks	16.0	22.6	27.6	41.2			30.2	34.5	35.6	14.2		
	Ringed	15.8	21.0	25.1	32.9	+8.3	+20	31.7	34.6	34.9	9.2	+5.0	+35

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* In analyzing these data the writer has in view the *retarding* effect of ringing; hence, if there is retardation, a figure representing that retardation is given a plus sign, and correspondingly, if there is acceleration of growth, it is considered a negative retardation and designated accordingly.

ference in percentage of growth of the check and ringed shoots, divided by the percentage of growth of the checks. The resulting quotient will be a decimal fraction which may be changed to a convenient integer by multiplying by 100. Values so obtained are given in the last column of each section of the table, representing a ringing date; through ignorance of a better term these are designated "coefficient of relative growth." If the sign of the coefficient is plus, a *retarding,* and if minus an *accelerating* effect on growth is indicated. Using the relative growth coefficients the graphs shown in Fig. 26 by solid lines were plotted from Table XIII. These graphs for both varieties are alike in showing an acceleration of growth by ringing on May 21 and retardations on dates earlier or later.

Table XIII, as stated, is a summary of the performance of all shoots under observation. But on examination of the records of individual trees, it was noticed that there was considerable difference among the trees as regards their growth response. Analyzing these differences,

TABLE XIV. EFFECTS OF RINGING ON GROWTH OF SHOOTS

Trees of Group 1 only. Series E.

		Date of ringing									
		May 9					May 21				
Variety	Treatment	Length of shoots 5/9	Length of shoots 5/21	Increase from 5/9 to 5/21	Difference check minus ringed	Coefficient of relative growth	Length of shoots 5/21	Length of shoots 5/31	Increase from 5/21 to 5/31	Difference check minus ringed	Coefficient of relative growth
		cm.	*cm.*	%	%		*cm.*	*cm.*	%	%	
Grimes	Checks	8.5	16.4	93.0			14.7	20.2	37.0		
	Ringed	8.4	13.4	59.0	+34.0	+37	15.2	22.0	44.8	—7.4	—20
Arkansas Black	Checks	4.8	10.6	121.0			10.8	14.4	33.3		
	Ringed	4.8	8.9	85.0	+36.0	+30	10.8	15.3	41.6	—8.3	—25

		Date of ringing									
		May 31					June 27				
Variety	Treatment	Length of shoots 5/31	Length of shoots 6/15	Increase from 5/31 to 6/15	Difference check minus ringed	Coefficient of relative growth	Length of shoots 6/27	Length of shoots 7/17	Increase from 6/27 to 7/17	Difference check minus ringed	Coefficient of relative growth
		cm.	*cm.*	%	%		*cm.*	*cm.*	%	%	
Grimes	Checks	19.6	24.1	23.0			25.0	26.8	7.2		
	Ringed	19.9	23.8	19.6	+3.4	+15	26.5	27.4	3.4	+3.8	+53
Arkansas Black	Checks	16.0	22.7	41.9			30.0	34.2	14.0		
	Ringed	15.7	21.2	35.0	+6.9	+16	31.5	34.7	10.2	+3.8	+27

it was found that the trees could be placed readily, according to their individual response, into one of the three following groups:

1. Trees giving graphs characteristic of those plotted from the complete summaries of Table XIII. This was the largest group, and was represented by 15 Grimes and 22 Arkansas Black, or 50 percent and 67 percent of the trees, respectively.

2. Trees giving graphs showing an acceleration effect at the first ringing date, May 9, and after that date a continually increasing retarding effect—a situation which may be explained perhaps by assuming that these trees were placed under observation too late in the season to show the first retarding effect of ringing. To this group belonged 10 Grimes and 9 Arkansas Black trees, or 33 percent and 27 percent respectively.

TABLE XV. EFFECTS OF RINGING ON GROWTH OF SHOOTS

Trees of Group 2 only. Series E.

		Date of ringing									
		May 9					May 21				
Variety	Treatment	Length of shoots 5/9	Length of shoots 5/21	Increase from 5/9 to 5/21	Difference checks minus ringed	Coefficient of relative growth	Length of shoots 5/21	Length of shoots 5/31	Increase from 5/21 to 5/31	Difference check minus ringed	Coefficient of relative growth
		cm.	*cm.*	%	%		*cm.*	*cm.*	%	%	
Grimes	Checks	8.5	13.0	53.0			14.9	18.9	26.9		
	Ringed	8.7	15.0	72.0	—19.0	**—36**	15.5	19.1	23.2	+3.7	**+14**
Arkansas Black	Checks	4.6	9.1	98.0			11.0	16.4	48.0		
	Ringed	5.0	10.7	114.0	—16.0	**—17**	11.1	14.6	31.5	+16.5	**+34**

		Date of ringing									
		May 31					June 27				
Variety	Treatment	Length of shoots 5/31	Length of shoots 6/15	Increase from 5/31 to 6/15	Difference check minus ringed	Coefficient of relative growth	Length of shoots 6/27	Length of shoots 7/17	Increase from 6/27 to 7/17	Difference check minus ringed	Coefficient of relative growth
		cm.	*cm.*	%	%		*cm.*	*cm.*	%	%	
Grimes	Checks	19.4	23.0	18.5			25.1	26.9	7.2		
	Ringed	20.0	22.8	14.0	+4.5	**+24**	26.7	27.4	2.6	+4.6	**+64**
Arkansas Black	Checks	16.1	22.3	38.5			30.3	34.6	14.2		
	Ringed	15.9	20.2	27.0	+11.5	**+30**	31.8	34.6	8.8	+5.4	**+38**

3. Trees showing various, apparently inexplicable, irregularities. Here must be placed 5 Grimes and 2 Arkansas Black trees, representing 17 percent and 6 percent respectively.

Table XIV was prepared from the total averages of the trees of the first group above. The graphs plotted from the coefficients of relative growth of group 1 only are shown by the heavy broken lines of Fig. 26. They are seen to differ from the solid line graphs chiefly in showing greater contrasting of effects, as was to be expected.

The data for the second group of trees are presented in Table XV and the corresponding curves of relative growth in Fig. 26, where they are shown by the short-broken lines. These graphs show a growth acceleration effect by ringing on May 9, but retardation on all other dates.

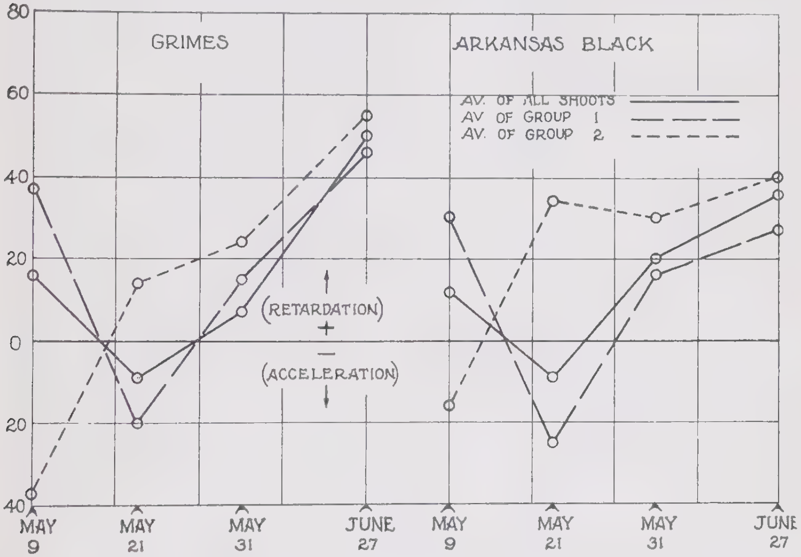

Fig. 26. Effects of ringing on growth of shoots. Series E. Graphs plotted from the "coefficients of relative growth."

The trees of group 3 above are given no consideration other than that they play their part, as previously stated, in the total summaries of Table XIII.

The results of this experiment are in general harmony with the findings of the experiments previously detailed in this report, and seem to corroborate the early inferences made from them. It is unfortunate, however, that a study corresponding to this was not made for defoliation.

The diverse growth responses observed for ringing and defoliation in the experiments of series A, B, and E, would seem to justify a restatement and extension of the explanation for such responses suggested early in this report. The explanation offered appears to apply equally to the various growth responses of both ringing and defoliation; if it were extended deductively beyond the experimental data so as to include the entire season of shoot growth, the treatments mentioned, considered singly, may be expected to affect growth at different stages somewhat as follows: (1) If the shoot is emerging from the bud or is still extremely undeveloped and practically all nourishment is coming from "below," *ringing** will greatly retard growth or almost completely stop it, and *defoliation* will retard growth also, but rather slightly as compared with ringing. (2) If the shoot is growing very rapidly, but the season is still very early, and the leaves are making a substantial contribution of nourishment, *ringing* will retard growth much less than in the preceding case, but *defoliation* will retard growth correspondingly more. (3) If growth is near the maximum, or, probably, shortly past maximum, and the general movement of elaborated foods is now "downward" from the shoot, *ringing* will retard growth very slightly, or may considerably accelerate it, but *defoliation* will have its greatest retarding effect. (4) Toward the close of the growth period, when the accumulation of carbohydrate materials in the shoot is already tending to throw the growth mechanism out of adjustment, *ringing* again will greatly retard growth and *defoliation* will, for the first, and only,

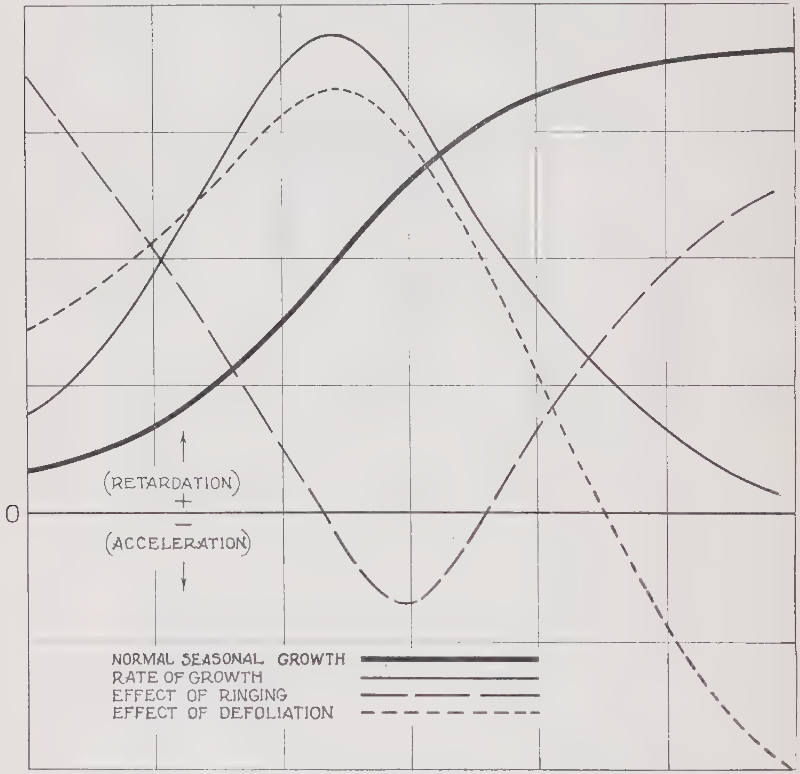

Fig. 27. Curves illustrating how the different effects of ringing and defoliation on growth depend upon the stage of development of the shoot. The "rate of growth" curve is estimated from the normal seasonal growth curve (which is adapted from Reed). The words "retardation" and "acceleration" refer only to the effects of ringing and defoliation.

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*Such ringing would have to be made in the branch just below the new growth.

time in the season, accelerate it. According to the above assumptions a curve representing the relative *retardation* of growth due to *ringing* might approximate the *reciprocal* of the normal seasonal *rate of growth curve* (developed from, but not the growth increment curve,* by which growth is usually shown). Therefore such a retardation curve would be high at the beginning of the season, and drop to a minimum at the maximum growth rate period, but now, in order fully to represent the effects of ringing, it should be brought below the axis of abscissas, probably at a point a little to the right of the growth rate maximum, to indicate there *negative retardation* (i.e., acceleration). From this point it would rise to the end of the season (see Fig. 27). A curve representing the relative *retardation* due to *defoliation* might correspondingly approximate the *rate of growth curve* itself, perhaps departing from it most toward the end of the season where it should pass considerably below the axis of abscissas to indicate that defoliation then accelerates rather than retards growth (see Fig. 27).

6. SERIES D

Series D was a study of the superficial effect on shoot growth of different types of defoliation. The study holds a somewhat supplementary relation to the preceding experimental series, although it was carried out prior to Series E, and introduced a new element in the methods employed. All defoliations were done on the same date, so that the work, unfortunately, is not comparable with the ringing experiments of Series E.

The shoots for the present experiments were furnished by three eight-year-old trees of the varieties Grimes, Spitzenburg, Gano, and Rome. Three types of defoliation were used; namely, (1) complete defoliation of the upper portion of the shoot, leaving a basal portion 7 to 10 cm. long (as in the defoliations of Series B), (2) the removal of every other leaf from the lowest basal leaf to the growing tip, and (3) complete defoliation of the basal portion only. These defoliations were designated "upper," "alternate," and "basal" respectively. Ten shoots of each of the three types of defoliation, and ten checks, were placed under observation on each tree. The defoliations were made June 6, and the measurements June 7, July 1, and August 15.

A summary of the performance of the check and defoliated shoots is presented in Table XVI. For the sake of brevity, the first and last measurements only are given. There is considerable variation in the growth responses of the shoots with the type of defoliation received. Defoliation of the upper portion of the shoot retards growth noticeably less than either of the other two types. By "upper" defoliation the Grimes and Rome shoots have growth accelerated and the Spitzenburgs have it retarded. The relative effects of upper defoliation in any of the four varieties are not difficult to explain on the basis of previous experiments, for both the type of defoliation and the responses appear to correspond exactly with the previous experiments and conclusions. Here the Grimes shoots were growing very slowly and were near the end of their growing season; the result was an acceleration of growth. On the other hand, the Spitzenburgs were still growing rapidly and responded oppositely. But a difficulty is introduced by the observed responses to "basal" and "alternate" defoliation, where growth is always retarded more than in the case of "upper" defoliation. This seeming fact of

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* The curve used in Fig. 27 is adapted from Reed.[9]

TABLE XVI. EFFECTS OF DIFFERENT KINDS OF DEFOLIATION ON GROWTH OF SHOOTS

Series D

Variety	Treatment		Length June 6	Length Aug. 5	Total increase	Percentage increase	Difference check minus treated	Coefficient of relative growth
			cm.	*cm.*	*cm.*	%		
Spitzenburg	Checks		18.8	34.3	15.5	82.5	......	....
	Defoliated	Alternate	24.2	42.0	17.8	73.5	+9.0	+11
		Basal	24.8	39.0	14.2	57.2	+25.3	+31
		Upper	26.5	44.3	17.8	67.1	+15.4	+19
Gano	Checks		17.1	25.2	8.1	47.4	......	....
	Defoliated	Alternate	17.1	22.9	5.8	33.9	+13.5	+28
		Basal	20.2	25.4	5.2	25.5	+21.9	+46
		Upper	21.8	30.7	8.9	40.8	+6.6	+14
Rome	Checks		17.5	25.9	8.4	48.0	......	....
	Defoliated	Alternate	17.7	22.9	5.2	29.4	+18.6	+39
		Basal	23.9	31.4	7.5	31.4	+16.6	+35
		Upper	21.2	32.3	11.1	52.4	—4.4	—9
Grimes	Checks		13.9	15.8	1.9	13.7	......	....
	Defoliated	Alternate	14.8	15.7	0.9	6.1	+7.6	+55
		Basal	18.4	19.5	1.1	6.0	+7.7	+56
		Upper	20.4	33.4	13.0	63.7	—50.0	—364

greater retarding effect of basal defoliation, for instance, is not easy to explain on a basis of decreased carbohydrate supply alone. But if toward the end of the growing season, the shoot normally draws most of its carbohydrate supply from the activities of its upper leaves, and the basal leaves tend to give up a considerable amount of their nitrogen (from chlorophyll, etc.) to the growing point for its late season activity, the response of the shoots to basal defoliation might thus be easily explained. The extreme cases are Grimes and Spitzenburg, where in the former growth is greatly accelerated by "upper," but apparently retarded by "basal" defoliation, and in the latter, both treatments retard growth about equally. It should be remarked, however, that the results recorded in Table XVI may not be as conclusive as desirable, since only thirty shoots of each variety and treatment were under observation. The growth made by the check shoots, moreover, was sometimes very little. For the Grimes shoots it is reasonably certain, however, that "upper" defoliation greatly accelerated growth, but the retardation of growth attributed to "basal" defoliation is questionable, on account of the checks having grown so slightly.

7. APPLICATION

The foregoing results have a general bearing on the question of growth responses to pruning, and they should aid in a better understanding of the various and often widely divergent pruning responses reported in horticultural literature. It is to the problem of summer pruning, particularly, that the present findings appear to have direct application, hence one finds it difficult to refrain from turning over in mind this once popular problem, in the light of the observations on growth of shoots as affected by ringing and defoliation. The varying degrees and frequently the complete reversals of effects produced by these treatments immediately suggest the fortuitousness of summer pruning as a means of accomplishing a definite result. This suggestion is further emphasized by some of the present observations on ringing. Certain of these indicated that the nutritive mechanism in the shoot may be so delicately balanced that the range of individual differences in two adjacent trees of the same variety may be sufficient so that ringing on the same day will produce completely opposite results. The conclusion may also be drawn from the results of Series D, that the type of growth response to to be expected of a defoliated shoot will depend not only on its stage of development, but also on the portion of the shoot receiving defoliation.

It is of course, easily conceivable that with a general knowledge of the various responses to be taken into account, and having much personal experience with a specific location and variety, an operator could proceed to summer-prune with considerable certainty; but as a horticultural procedure in the hands of the fruit grower himself, it would seem that summer pruning will long remain extremely impracticable.

The results presented concerning the chemical transformations taking place in the bases of variously treated shoots would allow the inference that one of the most important chemical changes accompanying regeneration in the stub of a severely headed shoot, as in summer pruning, is indicated by a relatively large increase in water, nitrogen, and other soluble materials, and a decrease in total carbohydrates as well as in the value of the carbohydrate-nitrogen ratio.

SUMMARY

1. A study, extending through a growing season, of normal chemical changes in different regions of apple shoots showed that—

a. Relatively large chemical differences obtain between the tip, middle, and basal regions.

b. Substances which tend, normally, to decrease through the growing season are always most abundant in the tip and least abundant in the base. Representative of this group are: water, soluble solids, phloridzin, and nitrogen.

c. Substances which tend to increase through the growing season are always least abundant in the tip and most abundant in the base. Representative of the group are: insoluble solids, sugars, polysaccharides, and total carbohydrates (and, with respect to value, the carbohydrate-nitrogen ratio).

d. The substances named in paragraph "1 *b*" above, are those commonly associated with good growth conditions. They are not only most abundant in the tip, but decrease there less rapidly through the season; indicating thereby more constant growing conditions in that region than previous analyses, involving the entire shoot, were able to show.

2. Defoliation was found to accelerate or retard growth according to the stage of development of the shoot; and, to some extent, according to the portion of the shoot defoliated.

3. Ringing also accelerates or retards growth according to the stage of development. But if ringing accelerates growth, defoliation under the same conditions will nearly always retard it, or vice versa. Very early in the season, however, growth will be retarded by either operation.

4. By ringing shoots at intervals through the growth season, a complete reversal of the effects of ringing was demonstrated; that is to say, early in the season ringing retarded growth, later accelerated, and finally retarded it again.

5. Ringing plus defoliation stops growth in a short time.

6. The basal 6 to 8 centimeters of shoots which received ringing or defoliation, or both, showed regenerations varying with the treatment. In the order of decreasing regenerative activity the treatments held the following positions: ringing plus defoliation, ringing only, defoliation only, and checks. The amount of activity through this series ranged from very considerable to none.

7. The chemical changes produced in the upper portions of shoots by defoliation are indicated by an increased percentage of water, soluble solids, phloridzin, and nitrogen; and a decrease of insoluble solids, sugars, starch, pentosans, total polysaccharides, total carbohydrates, and the carbohydrate-nitrogen ratio.

8. In the bases of same defoliated shoots, the chemical changes indirectly induced differed only from those of the upper defoliated portion in being less in degree.

9. The chemical changes produced by ringing were, in the upper portion of the shoot, the reverse of those enumerated as effects of defoliation, that is to say, water, soluble solids, phloridzin, and nitrogen were decreased, while insoluble solids, sugars, starch, and pentosans, etc., were increased.

10. Ringing plus defoliation produced the most striking chemical changes observed. The responses of the upper portion of the shoot were the same in quality, however, as those noted above for defoliation. Carbohydrates were probably the limiting factor to growth in these shoots, since their content of water and nitrogen was the highest.

11. The chemical changes produced in the bases of shoots which (in their top portions) received ringing, defoliation, and ringing plus defoliation were all the same quality with the responses mentioned for defoliation and ringing plus defoliation. But in the order of decreasing quantity of the chemical responses, the various treatments stood as follows: ringing plus defoliation, ringing only, defoliation only, and checks. This order is identical with that given for regenerative activity in these bases, a fact which is considered significant.

12. A general explanation was offered to unify the diverse growth responses of shoots to ringing and defoliation. Tentative curves also were prepared to illustrate the various responses to ringing or defoliation to be expected at different stages of shoot development.

13. Suggestions were made toward an application of the recorded findings to the pruning question.

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